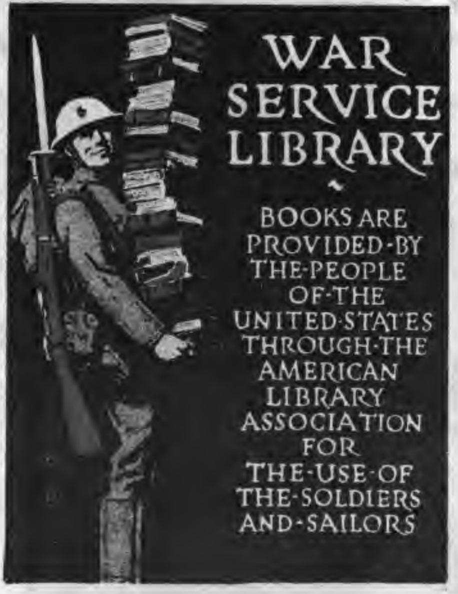
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NATURAL AND EXPERIMENTAL

PHILOSOPHY:

BY THE

REV. DAVID BLAIR,

AUTHOR OF A GRAMMAR ON CHEMISTRY, UNIVERSAL PRECEPTOR, &c. &c.

EIGHTH AMERICAN,

FROM THE TWELFTH LONDON EDITION,

IMPROVED AND ENLARGED.

A

GRAMMAR

OF

Natural and Experimental

PHILOSOPHY

INCLUDING

PHYSICS,	ACOUSTICS,
DYNAMICS,	OPTICS,
MECHANICS,	ASTRONOMY,
HYDROSTATICS,	ELECTRICITY,
HYDRAULICS,	GALVANISM,
PNEUMATICS,	MAGNETISM,

ACCORDING TO THE LATEST DISCOVERIES,

WITH ONE HUNDRED ENGRAVINGS ON WOOD.

BY THE

REV. DAVID BLAIR,

Author of the Class Book, Universal Preceptor, English Grammar, Reading Exercises, Models of Letters, &c.

C Phillips

TWENTY-FIRST EDITION,

From the Twelfth London Edition, Improved and Enlarged.

HARTFORD,

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1826.

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FROM THE AUTHOR'S

PREFACE

TO THE TWELFTH LONDON EDITION.

THE Author of the following pages is aware that there already exists several valuable but expensive books on Natural and Experimental Philosophy; and he should not have presumed to add to their number, except for the purpose of reducing an important branch of knowledge, in bulk and price, to the level of the business of schools, and adapting the whole to the present state of knowledge.

Every instructor of youth must be aware, that mere disquisitions are of no use in the art of teaching; and that no science can be taught, if the student does not *work* or perform operations in it; or answer *questions* which involve the consideration of its various details.

He who only reads *about* a science, can be nothing more than a *smatterer;* whilst he who commits its terms and elementary principles to memory, and applies them by some act of his own mind, to the various combinations of the science, soon becomes a *master* of it.

In strict conformity with this principle, this Grammar of Natural Philosophy has been compiled. All the definitions and elementary principles have been written with studied brevity, so that they may be learned by rote. With these have been intermixed such easy and familiar Experiments, Observations, and Illustrations, as will enable the young student to *work* in each science, while at the same time COPIOUS QUESTIONS have been annexed, for the purpose of adapting the book to the system of teaching by questions without answers.

The author cannot let pass this favourable opportunity, to express his sense of the honour which has been rendered to his humble endeavours, in the five works which he has already submitted to the public. He alludes to his CLASS BOOK, his UNIVERSAL PRECEPTOR, his EXERCISES IN READING, his ENGLISH GRAMMAR, and his MODELS OF JUVENILE LETTERS, in all of which he laboured diligently to give a popular feature to useful knowledge, and has met with his reward in the unparalleled success of those books.

A

GRAMMAR

OF

PHILOSOPHY.

OF MATTER AND ITS PROPERTIES.

1. MATTER is the general name of every thing or substance, that has length, breadth, and thickness.

Obs. Philosophers have in all ages discussed the general nature of matter, but without arriving at any satisfactory result. This is certain, that all we know of matter is merely relative to our own powers and senses; and those relative properties, being all we can know, are the proper objects of Philosophical inquiry.

2. The properties of all matter or substance, are SOLIDITY, DIVISIBILITY, MOBILITY, and INERTNESS.

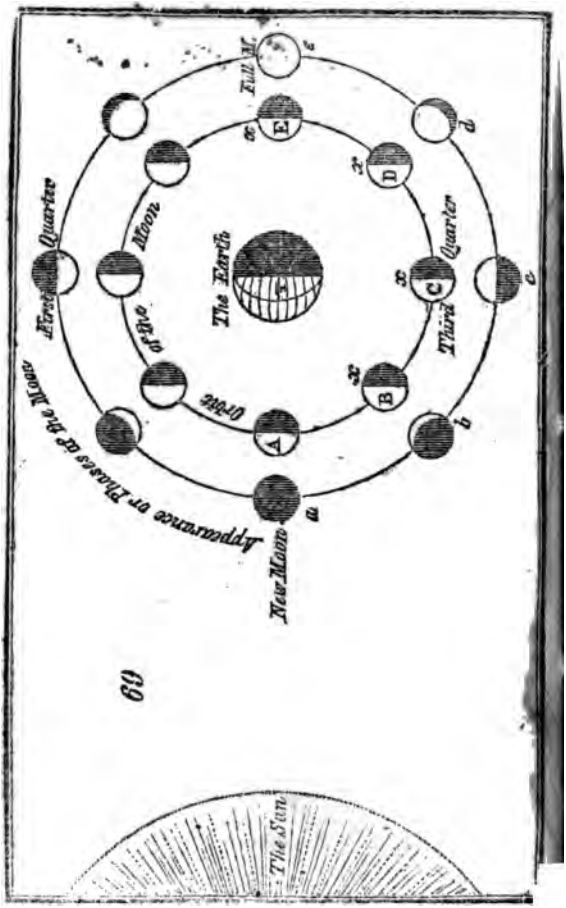
3. *Solidity* is that property which every substance possesses, of not permitting any other substance to occupy the same place at the same time.

Illustration 1. If a piece of wood or metal occupy a certain space, before any thing else can take possession of that space, the wood or metal must be removed.

2. Water and even air, have this property.

Experiment 1. If some water be put into a tube closed at one end, and a piece of wood be inserted that fits the inside of the tube very accurately, it will be impossible by any force to get the wooden piston to the bottom of the tube, unless the water is first taken away.

2. The experiment may also be made with air instead of water.



THE MOON'S PHASES.

Illus. It is found from experiment and observation, that all matter is capable of being moved, if a sufficient force can be applied for the purpose.

6. *Inertness*, or inactivity, is that property of matter by which it would always continue in the same state of rest or motion, in which it is put, unless changed by some external force.

Illus. 1. It is evident that matter, as a stone, can never put itself in motion, unless it be in some way acted upon.

2. Bodies in motion, as a bowl on the ground, or a cannon-ball passing through the air, fall from motion to a state of rest, either by the friction of the earth, by the gravity or weight of the body, or by the resistance of the air.

Exp. 1. A marble shot from the fingers would run but a small distance on a carpet: its motion would be continued much longer on a flat pavement; and longer still on fine smooth ice. Here the friction is greatest on the carpet, and least on the ice. If the friction were quite removed, and the resistance of the air also, the marble once put in motion would continue in that state for ever.

2. If a ball were fired from a cannon with a certain velocity, and there was no resistance from the air, it would circulate round the earth perpetually, and never come to a state of rest.

3. If a person were standing in a boat at rest, and the boat be suddenly pushed from the shore, he will be in danger of falling backwards. And if the boat in swift motion be stopt before he is aware, he will fall forwards, because his tendency will then be to continue in the same state of motion.

QUESTIONS ON MATTER AND ITS PROPERTIES.

What is *matter?*
What are the properties of matter?
What is *solidity?*
What is *divisibility?*
Give an example of the divisibility of matter.
What is *mobility?*
In what does this property of matter consist?
What is *inertness?*
What effect does inertness have on matter?
Why does not a body once put in motion always continue to move?

OF THE MECHANICAL AFFECTIONS (MATTER.

7. By Attraction is meant the tendency t dies have to approach each other whatever cause of such tendency.

8. There are five kinds of attraction: viz. traction of *cohesion;* of *gravitation;* of *electric magnetism;* and of *chemical affinity.*

9. The attraction of *Cohesion* is that by wh constituent particles of bodies are kept togethe this principle they preserve their forms and a vented from falling to pieces.

Illus. The attraction of cohesion takes place bet dies or atoms, only when they are at very small distar each other.

Exp. 1. If two leaden bullets are scraped very cl squeezed together, they will adhere so firmly as to r considerable force to separate them.

2. If two globules of quicksilver, be placed near e er, they will run together and become one large drop.

The result of sundry experiments made by profess schenbroek, to shew the *cohesive power* of different sol be seen in the following table In estimating the cohesion of solid bodies, he applied weights to separ according to their length; the pieces of wood which were parallelopipedons, each side of which was 27- an inch, and the metal wires made use of were 1-1 Rhinland inch in diameter, and they were drawn ası the following weights.—

	lb.		
Fir - -	600	Copper -	2
Elm - - -	950	Brass - -	3
Alder - -	1000	Gold - -	5
Oak - - -	1150	Iron - -	4
Beech - -	1250	Silver -	3
Ash - - -	1250	Tin - -	
	Lead -	29 1-4	

10. *Capillary* attraction is reckoned a species sion. The suspension of the fluid in capillary

owing to the attraction of the ring of glass contiguous to the upper surface of the fluid; and in capillary tubes, the heights to which the fluid rises are inversely as the diameter of the bores.

Exp. 1. If a small glass tube open at both ends, be dipt in water, the water will rise in the tube, higher than its level in the basin. The smaller the bore of the tube, the higher will the water rise.

2. Take two pieces of glass five or six inches square, join any two of their sides, and separate the opposite sides with a small piece of stick, so that the surface may form a small angle; then immerse them about an inch deep in a basin of coloured water, and the water will rise between the glasses and form a beautiful curve.

3. A piece of sugar or sponge, will draw up water or any other fluid upon the same principle.

11. It is, probably, owing to the various degrees of cohesion, that some bodies are hard, and others soft; that some are in a solid, others in a fluid state.

Obs As it is by the attraction of cohesion that the parts of a body are kept together; so when a body is broken, it is this attraction that is overcome. Hence the reason of soldering of metals, gluing of wood, &c. Hence also may be explained why some bodies are *hard*, others *soft*, and others *fluid*, which properties may result from the different figures of the particles, and the greater or less degree of attraction consequent thereupon. *Elasticity* may arise from the particles of a body, when disturbed, not being drawn out of each other's attraction; as soon, therefore, as the force upon it ceases to act, they restore themselves to their former position.

12. *Repulsion* is a force that is supposed to extend to a small distance round bodies, so as to prevent them from coming into actual contact.

Obs. 1. The repelling force of the particles of a fluid is but small, and, therefore, if a fluid be divided, it readily unites again. But, if a hard substance, as glass or sealing wax be broken, the parts cannot be made to adhere, unless they are moistened in one instance, or melted in the other.

2. Sir Richard Phillips who ascribes *attraction* to bodies mutually intercepting the impulse of a universal medium, acting *through all space*, ascribes *Repulsion* to vortices of eddys in the *circumambient medium*, produced by those peculiar causes

which always accompany high degrees of repulsive action. Th repulsion of electricity he considers as merely relative; be cause every electrified surface has within a given distance contrary electricity, and light bodies when apparently repelled from one surface, are, in truth, but attracted by the other surface; and perhaps all repulsion is produced by a counter attraction.

Exp. 1. Water repels most bodies till they are wet. A small sewing needle will swim in a basin of water.

2. Drops of water will roll on the leaves of many vegetables without wetting them.

3. If a ball of light wood be dipped in oil, and put into a pan of water, the water will be repelled from the wood, and will form a channel round it.

13. The attraction of *Gravitation*, or *gravity*, is the name of that force by which distant bodies tend towards one another.

Obs. 1. All bodies on or near the surface of the earth tend towards its centre by a power called *the attraction of gravitation*, or according to the writer above mentioned, by *intercepted pressure of an elastic medium*, which fills all space, and seeks to pervade all matter; and this seems a reasonable cause of the phenomenon. *Monthly Mag. Oct.* 1811.

2. A stone, or other heavy body let fall, will move towards the earth till it meet with some other body to obstruct its course. And bodies move in lines perpendicular to the surface, because the point to which they ultimately tend is the centre of the earth, and the line of direction produced coincides with the radius, and is at right angles with the surface, which is nearly spherical. Some bodies ascend, because they are acted upon by a force greater than the attraction of gravitation, and in a contrary direction. Vapours, smoke, &c. do not descend, because they are *lighter* than the air, and supported by it.

3. When we speak of *attracting powers*, we do not attempt to explain their nature or assign their causes. Having derived general principles or laws of nature, from phenomena we only give a name to these principles, in order to explain other appearances by them.

4. The tendency of all bodies towards the earth really results from their tendency towards the several parts of the earth. For, by an experiment made by Dr. Maskelyne upon *the side of the* mountain Schehallien, he found the attraction *of that mountain* sufficient to draw the plumb-line sensi *the perpendicular. See Hutton's Dictionary.*

14. By gravity, a stone dropped from a height falls to the surface of the earth; and by it the heavenly bodies are retained in their orbits.

15. The planets gravitate towards the sun, and towards each other, as well as the sun towards them.

16. By gravity all terrestrial bodies tend towards the centre of the earth, and in all places equally distant from the centre of the earth, the force of gravity is equal.

Obs. See the Monthly Magazine, May 1, 1813, for an account of the effects of *Pressure* of all terrestrial substances on each other; the above writer observes, that the power of PRESSURE acts from the surface to the centre of all planets, or independent totalities of matter NECESSARILY and WITHOUT INTERMISSION: and is, or has been, the great instrument or HANDMAID of NATURE, by which most of its VARIETIES of substance are, or have been produced. It is synonymous with the action or momentum of the *weight* of bodies in their endeavour to fall to the centre of planetary spheres, and with the impulse called by astronomers the *principle of gravitation.* It is evidently one of the primary principles of nature, and would drive all atoms of matter into solid and immoveable contact, but for another power called REPULSION, synonymous to elasticity, or expansion, producing varied degrees of density. To *press* and to *resist* appear to be the conflicting principles or agencies, to which we may ascribe all the phenomena of nature; and in the degree in which pressure overcomes resistance, or resistance counteracts pressure, heavy and light bodies, inert minerals, or active organizations, become the accidents, or necessary varieties, of those active powers. To PRESS and to RESIST appear then to be the active principles of all matter, or in other words, UNION by *gravity*, and EXPANSION by *heat*, seem to be the great secondary causes of all phenomena. The ELASTICITY of a universal medium producing action from *without* and substantial COMPRESSION *towards* a centre; and the ELASTICITY of heat producing action from *within* and EXPANSION *from* its respective centres, point out ELASTICITY as the generic moving power of Nature. And if Elasticity and its synonyme expansion, be a mere result of HEAT, and HEAT itself be merely a phenomonon of *motion*, then it would appear that MOTION itself, is the primary cause of all things! Nor is there any incongruity in referring to the same *primary cause*, the PRESSURE of gravity, and the EXPANSION *which opposes* gravity, because the elasticity of the medi

um of space producing gravity is *universal*, and the elastici producing expansion, is but *local* and *relative*."

17. The force of gravity is less at the equator th it is at the poles, because the equatorial diameter 24 miles longer than the polar diameter, and becau the swing, or centrifugal force of the earth at tl equator, diminishes the gravity.

Obs. Hence, seconds' pendulums, which in this latitu must be 39,2 inches, require to be 1-10th shorter, or but 39 at the equator.

18. The force of gravity is greatest at the earth's su face, from whence it decreases upwards and dow wards. It decreases upwards as the square of tl distance from the centre, and downwards simply the distance.

Obs. 1. The power of gravitation is greatest at the surfa of the earth, from whence it decreases both upwards and dow wards; but not in the same proportion. The force of gravi *upwards*, decreases as the *square of the distance* from the ce tre. That is, gravity at the surface of the earth, which about 4000 miles from the centre, is four times more power than it would be at double the distance, or 8000 miles from t centre. Gravity and weight may be taken in particular c cumstances, as synonymous terms. We say a piece of le weighs a pound, or sixteen ounces, but if by any means it cou be carried 4000 miles above the surface of the earth, it wou weigh only 1-4 of a pound, or four ounces; and if it could transported to 8000 miles above the earth, which is three tim the distance from the centre that the surface is, it would wei only 1-9th of a pound, or something less than two ounces.

2. It is demonstrated, that the force of gravity downwa decreases, as the distance from the surface increases, so that one half the distance from the centre to the surface, the sa weight, already described, would weigh only 1-2 a poun and so on.

Thus, a piece of metal, &c. weighing, on the surface of t earth, one pound, will at

at	The centre weigh			0
	1,000 miles from the centre,			1-4 pound.
	2,000	"	"	1-2
	3,000	"	"	3-4
	4,000	"	"	1
	8,000	"	"	1-4
	12,000	"	"	1-9th

and at the distance of the moon from the earth, which is 240,000 miles, it would weigh only the 3,600th part of a pound, because the distance is 60 times further from the centre of the earth than the surface.

QUESTIONS ON THE MECHANICAL AFFECTIONS OF MATTER.

What is meant by *attraction?*

How many kinds of attraction are there?

What is *cohesive* attraction?

What parts of bodies are affected by this kind of attraction?

What effect does it have on solid bodies?

Define what is meant by *capillary attraction?*

What is the rule in regard to the rise of fluids in capillary tubes?

How may this kind of attraction be illustrated?

What effect does the various degrees of cohesive attraction have on bodies?

What is the cause of *elasticity* in bodies?

What is *repulsion?*

Does this force act strongest in solids, or fluids?

What simple experiment will show that bodies repel each other?

What is *gravity*, or *the attraction of gravitation?*

To what point do bodies tend by this attraction?

What is the cause of this power?

What does the experiment of Dr. Maskelyne prove?

Is there any difference in the gravity or weight of the same body at different places, and why?

Why is it necessary that seconds' pendulums should be shorter at the equator than at the poles?

Where is the power of gravitation greatest?

In what proportion does it vary upwards, or downwards from the surface of the earth?

What would be the weight of a pound of metal here, when carried to the distance of the moon?

THE LAWS OF MOTION.

19. Motion is the continued and successive change of *place of any body.* Nothing can be produced or de-

stroyed without motion, and every thing that happens depends upon it.

20. Primary Laws of Motion are,

First, *That every body will continue in its state of rest, or of uniform motion, in a right line, until it is compelled by some external force to change its state.*

Secondly, *That the change of motion is always proportional to the moving force by which it is produced, and it is made in the line of direction in which that force is impressed.*

Thirdly, *That action and re-action are always equal and contrary.*

21. We are chiefly concerned with two kinds of motion.

1. That by which an entire body is transferred from one place to another.

2. The motion of the parts of bodies among themselves, supposed to be the cause of fluidity and vapour.

Illus. By the *first* kind of motion, a heavy body falls to the surface of the earth, a carriage moves, and a ship sails. By the *second*, plants and animals grow, and the compositions and decompositions of bodies take place.

Exp. Take a decanter of clear water, and hold it in the rays of the sun, and you will see that the light particles contained in it are in perpetual motion.

2. Let the rays of the sun pass through a small hole in window shutter, and you will observe the particles floating the atmosphere are in constant motion, of whose existe you were not before aware.

22. Several things require notice with reg motion:

1. The force which impresses the motion.
2. The quantity of matter in the moving bo
3. The velocity and direction of motion.
4. The space passed over in the moving b
5. The time employed in going over this sp
6. The force with which it strikes anoth that may be opposed to it.

23. **Every body, by its inertness, resists all change of state; therefore, to put a body in motion, there must be sufficient cause.**

Obs. Any body at rest on the surface of the Earth will always continue so, if no external force be impressed upon it to give it motion, and if the obstacle which hinders the attraction of gravitation from carrying it towards the centre be not removed. A body being put into motion by some external impulse, if all external obstructions were removed, and the attraction of gravitation suspended, would move on for ever in a right line; for there would be no cause to diminish the motion, or to alter its direction. This cannot be fully established by experiment, because it is impossible entirely to remove all obstructions; but, since the less obstruction remains, the longer motion continues, it may be reasonably inferred, that if all obstacles could be removed, motion once communicated to any body, would never cease.

Illus. 1. It is plain that a mass of matter, as a stone, cannot put itself in motion; it therefore would have for ever remained at rest, unless acted on by some power.

2. When a cannon ball is first discharged, it may be said to move in a straight line; and it is plain, that this would always be its direction, unless some power turned its course. It is also as evident, that it would always continue its motion forward, did not the friction of the air, or its own gravity, or some other cause so impede its motion, as to bring it to the ground.

24. The causes of motion are called motive powers, and are called muscular or mechanical: as the action of men and other animals, the force of wind, water, gravity, the pressure of the atmosphere, or any elastic medium, and steam.

25. The change of motion produced in any body, is proportional to the force impressed, and in the direction of that force.

Obs. Effects are proportional to their adequate causes. If, therefore, a given force will produce a given motion, a double force will produce the double of that motion. If a new force be impressed upon a body in motion, in the direction in which it moves, its motion will be increased proportionable to the new force impressed: if this force acts in a direction contrary to that in which the body moves, it will lose a proportional part of

its motion; if the direction of this force be oblique to the direction of the moving body, it will give it a new direction.

26. To every action of one body upon another, there is an equal contrary *re-action;* or mutual actions of bodies on each other are equal and in contrary directions, and are always to be estimated in the same right line.

Obs. Whatever quantity of motion any body communicates to another, or whatever degrees of resistance it takes away from it, the acting body receives the same quantity of motion, or loses the same degree of resistance, in the contrary direction: the resistance of the body acted upon producing the same effect upon the acting body, as would have been produced by an active force equal to, and in the direction of, that resistance. Hence it appears, that one body acting upon another, loses as much motion as it communicates; and that the sum of the motions of any two bodies in the same line of direction, cannot be changed by their mutual action.

27. The velocity of motion is estimated by the time employed in moving over a certain space, or by the space passed over in a certain time. The less the time, and the greater the space moved over in that time, the greater is the velocity.

Illus. 1. *To ascertain the degree of velocity,* the space run over must be divided by the time.

2. *To measure the space run over, the velocity must be multiplied by the time;* for it is evident, that if either the velocity or the time be increased, the space run over will likewise be increased.

3. If the velocity be doubled, then the body will move over twice the space in the same time: if the time be twice as great, then the space will be doubled: but if the velocity and time be both doubled, then will the space be four times as great.

Exam. 1. If a ship sail at the rate of 12 miles in an hour, or sixty minutes, then the velocity is equal to one mile in five minutes.

2. If two persons set out together on a journey, and one walks two miles and a half, and the other walks five miles, an hour, the velocity of the latter, will be double that of the former.

28. A body in motion must every instant tend to some particular point. In which case the motion will be in a *straight line,* or it may be continually changing the pe

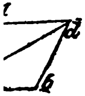
.h its motion is directed ; and this will produce linear, or circular motion.

If a body is acted upon only by one force, or by l forces in the same direction, its motion will be same direction in which the moving force acts.

ɪ. The motion of a boat, which a man at a given place ɔ him with a rope, is of this kind.

Equable motion is either simple or compound. motion is that which is produced by the action, ressed force, of one cause. *Compound* motion is ich is produced by two or more conspiring ɪ, i. e by powers whose directions are neither te nor co-incident.

If two or more forces, differently directed, act ıe same body at the same time, as it cannot obey ll, it will move in a direction somewhere be- them. This is called *the composition and re- n of motion.*



Illus. Suppose a body *a* to be acted upon by another body in the direction *a b*, while at the same time it is impelled in the direction *a c*, then it will move in the direction *a d*. If the lines *a b*, and *a c*, be made in proportion to the forces and the lines *c d*, and *d b*, rn parallel to them, so as to complete the parallelo- ıen the line which the body *a* will describe, will be in onal *a d*, and the length of this line will represent the th which the body will move.

ı. 1. There are many instances in nature, of motion pro- y several powers acting at the same time. A ship driv- ıe wind and tide is one : so also is a paper kite, acted the wind in one direction, and by the string in another. ɔall fired from a cannon is acted upon by two forces, is that occasioned by the powder, the other is the gravity.

The force, or power of overcoming resistance, moving body, is as its momentum, or quantity of

Since a body having a certain degree of motion is able ome a certain degree of resistance, it is manifest, that increased momentum, it will be able to overcome a *resistance.* Hence the momentum of any body is *l by its power* of overcoming resistance.

33. In moving bodies, if the quantities of matter be equal, the *momenta*, or quantity of motion, will be as the velocities.

Obs. If the body A be equal to the body B, but A has twice the velocity of B, A has twice as much motion as B.

34. The velocity of two bodies being equal, their momenta will be as their quantity of matter.

Obs. If the bodies *a* and *b*, fig. 1. move with equal velocities, since every portion of matter in *a* has as much motion as an equal portion of *b*, it is evident, that if *a* has twice the quantity of matter of *b*, it must have twice as much motion.

35. The momenta of moving bodies, are in the compound ratio of their quantities of matter and velocities.

Obs. The greater quantity of matter there is in any body, and the greater velocity it moves with, the greater will evidently be its quantity of motion, and the reverse. If, for example, the body A be double of the body B and moves with twice its velocity, the momentum of A will be quadruple of that of B: for it will have twice the momentum of B from its double quantity, and also twice the momentum of B from its double quantity of matter. Hence, if in two bodies, the product of the quantities of matter and velocities are equal, their momenta are equal, or as the products.

QUESTIONS ON THE LAWS OF MOTION.

What is *motion?*

What are the primary laws of motion?

What are the several things to be noticed in regard to motion?

What are the causes of motion?

How do moving bodies gain a new direction?

What is meant by *reaction?*

How is the *velocity* of motion estimated?

What is the rule for ascertaining the degree of veloci

What is the rule for measuring the space run over?

What is understood by *simple* and *compound* motion?

What is understood by the *composition* and *resolu* motion?

How is this kind of motion illustrated?

What proportion is there between the force or p moving body, and its momentum?

Illustrate this law.

What proportion do the *momenta* of moving bodies bear to heir velocities?

Illustrate the law.

When are the momenta of moving bodies equal?

OF ACCELERATED MOTION.

36. *Accelerated* motion is that in which the velocity s continually increasing from the continued action of he motive power. *Uniformly accelerated* motion, is hat in which the velocity increases equally in equal imes.

Illus. 1. The increasing velocity with which a body falls o the earth, is an instance of accelerated motion, which is aused by the constant action of gravity.

2. A cannon ball is acted on by a single impulse of the powler and the accelerating force of gravity, it therefore decribes a curve. This is the foundation of the art of gunnery.

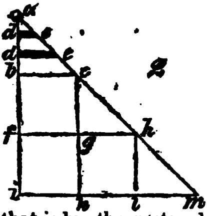
37. A new impression being made upon a falling body, at every instant, by a continued action of gravity, and the effect of the former still remaining, the velocity continually increases.

Illus. Suppose a single impulse of gravitation, in one instant, o give a falling body one degree of velocity; if after this the orce of gravitation were entirely suspended, the body would continue to move with that degree of velocity, without being accelerated or retarded. But, because the attraction of gravitation continues, it produces as great a velocity in the second instant, as in the first; which being added to the first, makes the velocity in the second instant, double of what it was in the first. In like manner, in the third instant, it will be tripled; quadrupled in the fourth; and in every instant one degree of velocity will be added to that which the body had before; that is, the motion will be uniformly accelerated.

38. Motion is said to be *retarded*, if its velocity continually decreases; and to be *uniformly retarded*, if its velocity decreases equally in equal times.

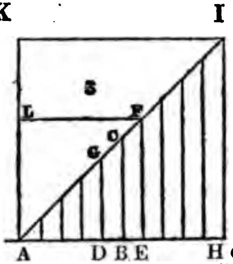
Obs. The student who has not learnt some Algebra and Geometry, may go to Article 40 without disadvantage.

39. The velocities of falling bodies, are in proportion to the spaces run over, and the spaces passed over in each instant, increase as the odd numbers 1, 3, 5, 7, 9, &c.



Illus. The space descrit falling from *a* fig. 2, in the t ed by *a b*, with a uniformly velocity, represented by th which the last degree is e: *c*, will be represented by the triangle *a b c*. If gra act, the space passed ove portion of time *b f*, would by *b f*, multiplied into the that is by the rectangle *b c g f*, which is equal t triangle *a b c*. But if gravity still acts, then the t must be added; of course, the body moves over the space in the second instant that it did in the next portion of time it would move over five tim represented by the two rectangles and triangle; fourth portion of time, seven times; and so on i cal progression.

It follows, that the *whole* space described, is s of the time; that is, in twice the time, it will fall times the space; in thrice the time, nine times th



Illus. The time of a falling body being re any portion A B of the angle, the velocity wi tional to B C, which i B, and the space desc the time D E, suppo short, will be propor area D E F G, which by the product B C, an quently the whole are represent the space described in the time A E a space described in the time A H; but A H I i square H K, and A E F of E L; the space is ways as the square of the time and is equal to h which would be described in the same time with locity.

Obs. All bodies descending in vacuo, are f through 16.1 feet in one second, and to acquire falling which would carry them uniformly throu in the next second, and an increase of velocity, is found to be added to every succeeding second

2. In the first instant there is one space run through; at the end of the second, there are four; at the end of the third, nine; and so on.

40. It has been found by experiment, that a body falling from a height, moves at the rate of about 16 feet in the first second of time; in the next 48, in the third 80, in the fourth 112 feet, and so on.

Exam. The space will therefore be 16 in the *first* second; 16+48, or 64 equal to 16X4: 4 being the square of 2, in the *second* second; 16+48+80, or 144 equal to 16X9: 9 being the square of 3, in the *third* second: 16+48+80+112, or 256 equal to 16X16; 16 being the square of 4, in the *fourth* second. And so on, because 4, 9, 16, &c. are the squares of 2, 3, 4, &c.

41. The *force* with which a body moves, or which it exerts upon another body, is always in proportion to its *velocity* multiplied by its weight, and this force is called the *momentum* of the body.

Illus. If two equal bodies move with different velocities, their forces or momenta are in proportion to their velocities.

Exp. 1. If two equal cannon-balls be projected by different quantities of powder, so that the velocity of the one is double that of the other, then the force or momentum of the former will be double that of the other.

2. If two stones, one of two pounds, and the other of six pounds be hurled with equal velocities, the force or momentum of the latter will be three times greater than that of the former.

Corol. In all cases, the *momenta* of bodies must be as the quantities of matter multiplied into the velocities.

QUESTIONS ON ACCELERATED MOTION.

What is *accelerated* motion?
What is meant by *uniformly* accelerated motion?
What causes acceleration of motion?
Why does a ball shot out of a cannon describe a curve?
When is motion said to be *retarded*?
Demonstrate the laws of falling bodies by a diagram.
What laws do falling bodies observe in a vacuum?
At what rate are the velocities of falling bodies increased?
What is the rule for estimating the force of a moving body?
Illustrate this rule.

OF CENTRAL FORCES.*

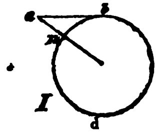
2. All motions produced upon a body, by on .e only, must be made in a right line.

herefore, a body moving in a curvilinear direction mu icted upon by two forces at least; and when one of thes ses to act, the body will move again in a straight line.

Illus. A stone in a sling is moved round by the hand, whil is pulled towards the centre of the circle which it describ y the string. But when the string is let loose, the stone fli ff in a tangent to the circle.

43. The force which impels a body towards a centr when it revolves in an orbit, or circle, is called the *cen tripetal* force; that by which it endeavours to reced from the centre, is called the *centrifugal* force; an these combined forces are called *central* forces.

Obs. The projectile and centrifugal forces differ from eac other, as the whole from the part. The projectile force is th by which a body would move forward in a tangent to its orb if there were no centripetal force to prevent it: the centri gal force is that part of the projectile force which carries body off from the centre while it is moving in the tangent.



2. When bodies revolve in a circular c about a centre, the centripetal and centrif forces are equal; because the periphe the circle is in the middle between the where the body would have been if i moved in a right line either towards the or in the tangent. If a body revolve in t cle *b* d, fig. I. in the time in which it describes the arc *b n*. have been impelled towards the centre, through the spa for by the projectile force alone, it would have been from *b* to *a*. The line *a n* is then the space descr means of the centripetal force, and this force is propor *a n*. But if, when the body was at *b*, no centripetal f

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* The doctrine of central forces will be studied v advantage in connexion with Astronomy, and may over by the junior student in this place, particularl not learned the first six books of Euclid, and th rules of Algebra.

›on it instead of describing the arc $b\ n$, it would have ılong the tangent $b\ a$ and the line $n\ a$ would have been e through which it would have parted from the cenerefore the centrifugal force is proportioned to $n\ a$.— ese forces being then proprotional to the same line $n\ a$, e equal to one another.

A body revolving in an orbit, describes by a ra'awn to the point towards which the centripetal ıcts, equal areas in eqnal times, and in unequal it describes areas proportional to the times.

1. The student will readily understand this proposihen he understands its terms. By areas is meant the ›ounded by the orbit and lines joined to the centre. elocities are equal, i. e. if the parts of a circular orbit ıal, the areas must be equal.

he velocity of a body, revolving freely about an imıle centre is *inversely*, as a perpendicular let fall from ntre on a right line that touches the orbit. For the es will be as the lines moved over, which being the baıual triangles, must be inversely as the heights of the es; therefore the velocities are as inversely as the , which are measured by perpendioulars, let fall from ımon centre.

'hen a body describes equal areas in equal times, about ıoveable point, or proportional areas in unequal times, t be impelled towards that point, by the centripetal vhich retains it in its orbit.

The centripetal forces of bodies, revolving in ınt circular orbits about the same centre towards they tend, are as the squares of the arcs describhe same time, divided by the radii of the circles.

l. Therefore, the centripetal forces of equal bodies ng in circular orbits, are as the squares of the velocities y, and as the radii of the orbits inversely.

. Because the length of arcs described in the same time, e in the proportiòn of the velocities, and the centripetal are as the squares of the arcs described in the same time, l by the radii ; these forces are also as the squares of the ies divided by the radii; that is, as the squares of the veı directly, and the radii of the orbits inversely. Hence ıtripetal forces of equal bodies, at equal distances from ıtre, are as the squares of the number of revolutions, in

any given time; for this number is as the velocity with the body moves.

46. The centripetal forces of equal bodies re ing in equal circular orbits, are inversely a squares of their periodical times.

Obs. The circular orbits or spaces being equal, the in which these are described, or the *periodical times*, a versely as the velocities; and therefore, the squares c periodical times are inversely as the squares of the velo or the squares of the velocities are inversely as the sq of the periodical times; but the centripetal forces are s squares of the velocities; therefore, these forces are in ly as the squares of the periodical times.

47. The centripetal forces of equal bodies, volving in unequal circular orbits, if the perio times are equal, are as the radii of the circles.

48. The centripetal forces of equal bodies, volving in circular orbits, are as the radii of the or or distances, directly, and as the squares of the odical times inversely.

Illus. If the periodical times are equal, and the radii qual, the force is as the radii. If the radii are equal, an periodical times unequal, the forces are inversely a squares of the periodical times. Therefore, if both the and periodical times are unequal, the forces will be i compound ratio of both, or as the radii directly, an squares of the periodical times inversely.

OF THE CENTRE OF GRAVITY.

49. The *centre of gravity* of a body, is that p about which all its parts do in any situation exactly lance each other, so that if a body be suspende supported by the centre of gravity, it will rest in position.

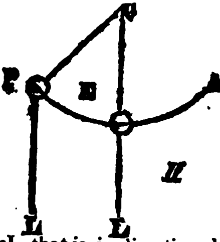
50. Whatever supports the centre of gravity b the weight of the whole body; therefore, the w weight of a body may be considered as balanced in *point.*

51. **The common centre of gravity of two or more bodies, is the point upon which they would rest in any position.**

Illus. If the centres of gravity of two bodies, AB. fig.3. be connected with the right line AB, the distances AC, and BC, from the common centre of gravity, C, are inversely as the weight of the bodies A and B; that is, the point of C will be as much nearer to A than to B, as A is heavier than B; that is AC : BC : : B : A.

Exp. Suppose A to be a ball of 12 pounds, and B to weigh only 4 pounds, and the length of AC to be five inches: then BC will be 15 inches: for it will be 5 : BC :: 4 : 12, or 4 X BC=5X12=60, and BC=20-4=15.

52. **The centre of motion is the point about which the body moves; and a heavy body suspended on a centre of motion will be at rest, if the centre of gravity is directly under, or above, the centre of motion.**



Illus. If a heavy body E, fig. II. hangs by a string on a centre of motion C, the action of gravitation at E is in the direction EL, contrary to the direction in which the string acts to prevent the body from falling. In this position, therefore, the opposite forces being equal in contrary directions, destroy each other, and the body is at rest. But if the body is at *p*, one of the forces acts in the direction *p*C: and the other in the direction *p*L, that is, in direction oblique to each other, whence the body will move in the diagonal of the parallelogram formed by *p*C, *p*L. And in all cases, since (without the aid of mechanical powers afterwards explained) the force which sustains any body must be equal to its weight, the centre of gravity can only be at rest when these forces are in the same line of direction, that is, when the centre of gravity is directly under, or directly above the centre of motion.

53. **If a line be drawn perpendicular to the horizon, from the centre of gravity of a body, it is called the *line of direction*, because it is the line which the centre of gravity would describe if the body were suffered to fall.**

54. While the line of direction falls within the base upon which the body stands, the body cannot fall; but if it fall without the base, the body will tumble.

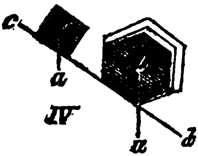
Illus. The inclined body *abcd*, fig. III. whose centre of gravity is *e*, stands firmly, because the line of direction *ef* falls within the base. But if the body *abgh* be placed upon it, the centre of gravity will be raised to *l*, and then the line of direction *ld* will fall out of the base; of course the centre of gravity is not supported, and the whole must fall.

Obs. This proves the injurious effect of rising in a coach or boat in danger of oversetting, the centre of gravity being thereby raised, and the line of direction thrown out of the base. Whereas, in such circumstances, the proper course is to lie down in the bottom, so as to bring the line of direction, and consequently the centre of gravity, within the base, and thereby remove the danger of oversetting.

55. The broader the base, and the nearer the line of direction is to the centre of it, the more firmly does a body stand; and the narrower the base of a body, and the nearer the line of direction is to the side of it, the more easily it is overthrown.

Obs. Hence a sphere is easily rolled along; and a narrow pointed body is with difficulty made to stand.

56. If a plane be inclined on which a heavy body is placed, the body will slide down upon the plane while the line of direction falls within the base; but will roll down, when that line falls without the b



Illus. 1. The body *e*, fig. IV. h the line of direction *ea* within the will only slide down: but the line rection *ba* of the body *b* falling the base, that body rolls down the

2. When the line of directi within the base of our feet, w and most firmly, when it is in the middle; but whe of the base, we fall unless we step out, and this is th of walking.

Rope-dancers are able to perform their feats by knowing exactly to keep the common centre of gravity, of them-s and their pole, just within the extended base.
We apply this principle in the common actions of life; we bend our bodies forward when we rise from a chair, up stairs;—so a man leans forward when he carries a 'en on his back, and to the right and left as he carries it e opposite side.

OF PENDULUMS.

'. A Pendulum is a heavy body hanging by a g or wire, which is moveable at a centre, and swing is called a *vibration* or *oscillation*.
s. The vibrations are produced by the falling of the it to the lowest part of the circle, and by the force ac-d in the fall.
:. All the vibrations of the same pendulum, w[illegible]h-eat or small, are performed in equal times; and onger a pendulum, the slower are its vibrations, quares of the times being inversely as the lengths.
). A pendulum that vibrates in the latitude of Lon-n a *second* of time, is thirty-nine inches two-tenths ; but a pendulum that vibrates seconds at the tor, must be but thirty-nine inches one-tenth.
). A pendulum, by 59, to vibrate half seconds must ie-fourth part as long, as one that vibrates seconds, a pendulum to vibrate once in two seconds must be times as long, as one which vibrates seconds.
s. 1. As it is found by experiment that a pendulum which tes 60 times in a minute is 39.13 inches nearly, therefore d how long pendulums must be to vibrate, 30, 50, and 120 in a minute, we say, by 50,

Inches. Inches.

$$\text{as } 30^2 : 60^2 :: 39.13 : 156.52$$
$$50^2 : 60^2 :: 39.13 : 56.34$$
$$120^2 : 60^2 :: 39.13 : 9.78$$

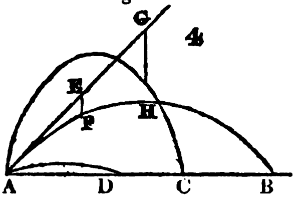
As heat expands and cold contracts all metals, a pendu-rod is longer in warm weather than in cold; and irregu-hence takes place in clocks.

The vibrations of pendulums are subject to many irre ...es, for which no effectual remedy has yet been devi se are owing partly to the variable density and temp of the air, partly to the rigidity and friction of the rod ..ch they are suspended, and principally to the dilatation traction of the materials, of which they are formed. ... tal rods of pendulums are expanded by heat, and contr by cold: therefore, clocks will go slower in summer, ster in winter. The common remedy for this inconvenie the raising or lowering the bob of the pendulum by m f a screw.

OF PROJECTILES.

61. **Bodies thrown horizontally or obliquely i the air, have a curvilinear motion, and the p which they describe is the curve, called a *parab***

Obs. 1. Very dense bodies moving with small velocities sc... the parabolic track so nearly, that any deviatio scarcely discoverable; but with very considerable veloci the resistance of the air will cause the body projected to scribe a path altogether different from a parabola, which not appear surprising, when it is known, that the resistan the air to a cannon-ball of two pounds weight, with the city of 2000 feet per second, is more than equivalent to times the weight of the ball.



Illus. The horizontal r fig. 4, AB, of a body p ed at an elevation of greater than AC or A ranges of bodies pr with the same veloc greater or less eleva the parallel lines EF always as the square AG, the curve AFH will be a parabola; and such is of a projected stone or cannon-ball.

QUESTIONS ON CENTRAL FORCES

What is meant by *central forces?*

When a body is acted on by only one force, in w tion does it move?

What is meant by *centripetal force?*

What is meant by *centrifugal force?*

What is the difference between the *projectile* and centrifugal forces?

When bodies revolve in an orbit, what proportions do the centrifugal and centripetal forces bear to each other?

Illustrate this by a diagram.

When do revolving bodies describe equal areas, and when do they describe unequal areas?

Illustrate these laws.

How are the centripetal forces of bodies, revolving in different circular orbits, about the same point determined?

How do you determine the centripetal forces of equal bodies, revolving in equal orbits?

How do you determine the centrifugal forces of equal bodies, revolving in unequal orbits, their periods being equal?

OF THE CENTRE OF GRAVITY.

What is the *centre of gravity* of a body?

How can the centre of gravity be found?

What is the common centre of gravity, of two or more bodies?

Illustrate this by a diagram.

What is the *centre of motion?*

Why will a heavy body, suspended on the centre of motion be at rest?

Demonstrate this by a diagram.

What is meant by the *line of direction?*

Where must the line of direction fall, to prevent a body from falling?

Illustrate this.

What practical inference may be drawn from this illustration?

Why is a body more apt to keep its perpendicular direction when set on a broad base, than on a narrow one?

How do rope-dancers contrive to keep their balance?

OF PENDULUMS.

What is a *pendulum?*

How are the oscillations of a pendulum produced?

What is the rule for calculating the time in which pendulums of different lengths vibrate?

What is the length of a pendulum vibrating seconds at London?

Why must it be shorter at the equator, to vibrate in the same time?

How long must a pendulum be to vibrate half secon London?

How long must a pendulum be to vibrate once in tw conds at the same place?

How long must a pendulum be, which vibrates forty t in a minute at London?

Why do clocks go faster in winter than in summer?

OF PROJECTILES.

What is the path called, which a body describes, w thrown horizontally, or obliquely into the air?

Is there any difference in the curves described by b moving at greater or less velocities?

Illustrate this difference by a diagram.

What resistance does the air oppose to a cannon ball of pounds weight moving at the rate of 2000 feet per second

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OF THE MECHANICAL POWERS.

62. The MECHANICAL POWERS are simple eng founded on the principles of the laws of mot which enable men to raise heavy weights, m heavy bodies, and overcome resistance.

Obs. 1. The principal moving powers are—first, strength of animals, chiefly that of men and horses; secon the force of running waters and of winds; thirdly, the for steam; fourthly, the force of springs; fifthly, the weig heavy bodies.

2. The simple weight, as applied to clocks, jacks, other machines, is the power which can be most easily plied as a first mover, and its action is almost uniform. this power requires to be renewed after a certain perio is mostly used for slow movements.

3. The spring is a useful moving power, but like the wei it requires to be wound up after a certain time, whence also chiefly used for slow movements.

63. Three circumstances are to be considere treating of mechanical contrivances:

1. The *weight* to be raised, or the *resistance* to be overc
2. The *power* by which it is to be raised; and
3. The *instruments* employed.

64. There are six mechanical powers; viz. the EVER; the PULLEY; the WHEEL and AXIS; the INLINED PLANE; the WEDGE; and the SCREW; the bject of which is to increase the effect of a given ower, so that the momentum of the power may xceed that of the resistence.

Obs. 1. If the power be 100 pounds, and the weight 1000 ounds, powers to move the weight must be made to move ith above ten times the velocity of the weight, and this is ffected by means of the mechanical powers.

2. If a man can raise by a single fixed pulley, a beam to the p of a house in two minutes; he will be able to raise six ich beams in twelve minutes; but with a tackle having three wer pulleys, he will raise six beams with the same ease at ice; but he will be six times as long about it, that is, twelve inutes, because his hand will have six times as much space pass over.

3. Cannon balls do much more mischief, than the battering ims of ancient times; suppose the weight of a ram to be 0,000 pounds, and to move at the rate of one foot in a second; id the weight of a cannon ball to be 24 pounds, and to move the rate of 1000 feet in a second, then the momentum or oving force of the ram, will be $20,000 \times 1 = 20,000$, and that the cannon will be $24 \times 1,000 = 24,000$; of course the effect the latter will be one fifth greater than that of the former. hus has a small body a greater momentum than a large one, *ovided the velocity of the small one be made to compensate for e greater quantity of matter in the other.*

65. The power of a machine is calculated, when it in a state of equilibrium, that is, when the *power* ist balances the *resistance* opposed, and the momenim of each is equal.

OF THE LEVER.

66. The LEVER is a bar of iron or wood, supported y and moveable on a round centre called a *fulcrum*, aving the *resistance* at the short arm, and the *power* t the long arm.

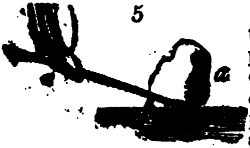
Obs. Levers of continuous matter as wood or metal are in ngle ratio; but levers of elastic media which *diffuse* the rce are a duplicate ratio.—*Phillips.*

67. There are *three* kinds of levers, dis according to the different positions of the *f* the moving *power* with respect to each oth

68. In all kinds of continuous levers, the p the resistncee, as the distance of the resis the fulcrum is to that of the power from th

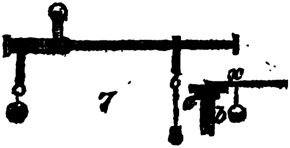
69. A lever of the *first* kind, is when tl is placed between the weight and the mov as in fig. 5.

5



Exam. If it be requ the stone *a*, which v pounds, by the streng equal to 100 pounds we *ce*, which rests on th placed with one end un and the man presses it other end *c*. As the man's strength is only equal part of the weight of the stone, the arm of the le be ten times as long as the arm *be*, in order tha and weight might balance each other.

6



7

Illus. 1. A *balance* is a lever of the first kind arms, see fig. 6.

2. A *steel yard*, fig, 7, is also the first kind of l moveable weight.

3. A *poker*, in the act or stirring the fire, is a kind: the bar of the grate upon which it rests is t the coals, the weight to be overcome; and the power.

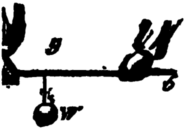
Obs. 1. To this kind of lever, may be refer *pincers*, *snuffers*, &c. which are made of two le contrary to each other. The fulcrum in these pin which keeps them together.

2. The lever of the first kind is chiefly used l large stones; or to raise great weights to small he der to get the ropes under them.

The *second kind of lever*, is when the fulcrum ie end, the power at the other, and the weight :n them.

l. See fig. 8, where *a* is the fulcrum, *b* the weight, ie power.

ie advantage gained by this lever is as great, as the dis- f the power from the fulcrum exceeds the distance of ght from it; thus if the hand at *c* be nine times as far as the point X on which the weight acts, then the force ound at *c*, will balance the weight *b* of nine pounds.

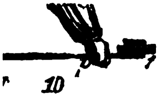


Illus. 1. This kind of lever explains why two men carrying a burthen, as a cask, upon a pole, may bear unequal shares, according to the strength, by placing it nearer to the one than the other; see fig. 9. Here the weight *w*, is iearer to *a* than *b*; of course, *a* would bear twice as reight as *b*.

his is applicable to the case of two horses of unequal h, where the beam may be so divided, that the horses aw up in proportion to their respective ability.

o this kind of lever may be referred oars, rudders of loors turning on hinges, and cutting knives which are t one end.

A lever of the *third kind* is when the prop is at id, the weight at the other, and the power applied en them. Here the power must exceed the t in the same proportion, as the distance of the t from the prop, exceeds the distance of the ·.



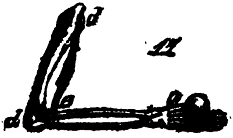
Illus. 1. Let *f* fig. 10, be the prop or fulcrum, *p* the power, and *w* the weight; if the distance *pf* be only three inches, and *wf* be twelve, then for the hand *p* to balance the weight is. will require a force of four times 20, or 80 lbs. be- he weight is at four times the distance from the ful hat the power is.

. 1. A ladder, which is to be raised by the strength of a irms, represents a lever of this kind, where the fulcrum is d which is fixed against the wall, or upon which another ands; the weight may be considered as at the top part of

the ladder, and the power is the strength applied tc ing of it

2. The wheels in clock and watch work, may ed levers of this kind, because the power that n acts near the *centre* of motion, by a pinion, and the it has to overcome, acts against the teeth at the *ence.*

3. The bones of a man's arm, and the greatest the moveable bones of animals, are levers of the thi



To take the arm, fig. 1 stance—*d* the elbow, is th motion, the power, is the serted at *c*, about one ter far below the elbow as t and *a* is the weight to be i muscles must according power equal to one hundred pounds to raise a we pounds.

Corol. Hence, in *natural* levers, the power is d geously situated, owing to the power being so near of motion, but the loss of power is compensated by and compactness of the limb.

69. A *hammer-lever* differs only in its for lever of the first kind.

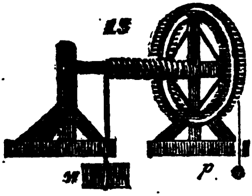
Illus. Let *a c b*, fig. 12, represer this kind, bended at *c*, which is th *p* is the power acting upon the long by means of the cord *a d* going over *d*; and the weight *w* acts upon t arm *c b*, of the lever. As *a c* is fiv long as *c b*, a weight of five pound balance 25 pounds at *w*.

Exp. If the shaft of a hammer is s long as the iron part that draws tl lower part *c* resting on the board *w* as a fulcrun pulling at *a*, a man will draw a nail with one-sixth power that he must use to pull it out with a pair in the latter case, the nail would move as fast as th in the former, the hand would move over six time space as the nail during the time of drawing it wood.

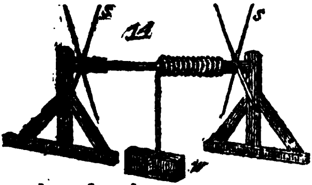
OF THE WHEEL AND AXIS.

73. The *wheel and axis*, though made in many forms, consists of a cylinder, and a wheel fastened to it, (*fig.* 13,) or of a cylinder with projecting spokes, (*fig.* 14.)

74. The advantage gained is in proportion as the circumference of the wheel is greater than that of the axis; or as the diameter of the wheel is greater than the diameter of the axis.



Illus. If the diameter of the wheel, fig. 13, or the length of the spoke, fig. 14, be four feet, and the diameter of the axis only 8 inches, then the power P, of one hundred lbs. or the strength of a man applied to the spokes S, equivalent to a hundred pounds, will balance a weight W of six hundred pounds.



In this case as in the lever, the power will travel over six times as much space as the weight, when the machine is put in motion.

Exam. 1. To this engine, cranes of all kinds for raising heavy weights may be referred.

2. Sometimes the axis is turned by a winch fastened to it, which serves for a wheel, and the power gained is in proportion as the winch is larger than the axis.

3. A capstan is a cylinder of wood, with holes in it; into these, bars are put to turn it round. The bars are made to act something like the spokes, fig. 14.

OF THE PULLEY.

75. The pulley is a small wheel turning on an axis with a rope passing over it. *See fig.* 15.

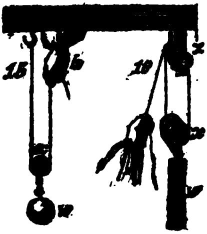
Illus. The small wheel x is called a sheeve, and is so fixed to a block a, as to be moveable round a pin passing through the centre.

76. Pulleys are either *fixed* or *moveable*.

Obs. 1. The fixed pulley gives no mechanical advai but is used only to change the direction of a power. B man may raise a weight to any height, without moving the place in which he is, as a stone to the top of a bui otherwise he must ascend with the weight.

77. The moveable pulley represented by x, fig is fixed to the weight, and rises and falls with it, the advantage gained by it is as 2 to 1.

1. The reason of this is evident, for in raising the w one inch, foot, or yard, both sides of the rope must be tened as much, that is, the hand h must move throug inches, feet, or yards; which shews, as before, that the through which the power moves, must always be in pr tion to the advantage gained.



2. When the upper *fixed* blo fig. 16, contains *two* pulleys, w only turn on their axis, and the l moveable block x contains also which turn and rise with the w W, the advantage gained is a to *one*. For each pulley in the l block will be acted upon by an part of the weight, and since in pulley that moves with the we double increase of power is ga therefore the advantage gained is as *four* to *one*.

78. In general the advantage gained by pulle found by multiplying the number of moveable pul by 2.

Obs. 1. A weight W of 72 lbs. may be balanced by moveable pulleys, by a power of nine pounds, because 7 vided by 8 gives 9; but in this case the power, when p motion, will pass over 8 times as much space as the we that is, to raise the weight one foot, the hand must move eight feet.

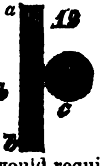
2. A pair of blocks with a rope is called a *tackle*.

OF THE INCLINED PLANE.

79. The inclined plane is merely a plane sur inclined to the horizon, and is used to move wei *from one level* to another, see *fig*. 17.

Obs. It is often made by placing boards, or earth, in a sloping direction, and is of great importance in rolling up heavy bodies, as casks, wheel-barrows heavily loaded, &c.

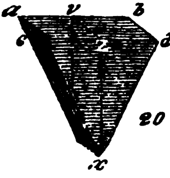
80. The force with which a body descends upon an inclined plane, is to the force with which it would descend perpendicularly, as the height of the plane is to its height.



Illus. If the plane *a b*, fig. 18, be parallel to the horizon, the cylinder *c* will rest on any part of it wherever it is laid. But if the plane be placed perpendicularly as *a b*, fig. 19, the cylinder will descend with its whole weight, and would require a power equal to its weight, to keep it from descending. Or, if the plane be inclined to the horizon as *a d*, fig. 17, and *three* times the length of the perpendicular *b d*, the cylinder *e* will be supported by a power equal to a *third* part of its weight. And if the plane be 20 feet long, and the perpendicular height be 4 feet, or *one-fifth*, then 500lbs. would be balanced upon it by 100lbs. because the plane is five times the length of the perpendicular height to which the weight is to be raised. To the inclined plane may be reduced *hatchets*, *chisels*, and other *edge tools*, which are sloped only on one side.

OF THE WEDGE.

81. The Wedge may be considered as two equally *inclined planes* united at their bases. The advantage gained is in proportion as the length of the two sides of the wedge is greater than the back, or as the length of one side is greater than half the back.



Illus. The wedge *a b c d x*, (see fig 20,) may be divided into two inclined planes, *a v c x*, and *b v d z x*, which may be used separately, and will gain advantage as such; therefore, when united at *z x*, the advantage gained will be in the same proportion, as when they were used in different parts.

Obs. When the wood cleaves at a distance

before the wedge, the advantage then gained is in proporti as one side of the cleft is greater than half the length of t back.

82. The wedge is a very important mechanic power, used to split rocks, timber, &c. which cou not be effected by any other mechanical power.

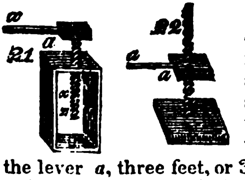
Obs. All instruments, and some sorts of chisels chamfi ed on both sides, are to be referred to the principle of t wedge.

OF THE SCREW.

83. The Screw is an inclined plane used with a l ver or winch to assist in turning it; and then it becom a compound engine of great force, either in pressi bodies closer together, or in raising great weights.

Obs. The screw may be conceived to be made, by cutt a piece of paper into the form of an inclined plane, and th wrapping it round a cylinder; the edge of the paper will fo a spiral line round the cylinder, which will answer to t thread of the screw.

84. The advantage gained by this mechanical po er, is in proportion as the circumference of the c cle made by the lever or winch is greater than t distance between the threads of the screw.



Illus. It is evident that the wir or lever will turn the cylinder o round, whilst the weight, or the r sistance, can be moved from o spiral winding to another, as fro to *s*, see fig. 21. If the distance the spirals *s x*, is half an inch, a the lever *a*, three feet, or 36 inches long, then the circle scribed by the lever will be about 228 inches, or 456 half in es, consequently a force at the end of the lever, equal to o one pound, would balance a resistance at the thread of 4 pounds. Hence it appears, that the longer the winch or ver, and the nearer the spirals, the more advantage is gair But in the screw there is great loss of power; for a screw n be moved upward or downward in a fixed nut, as in fig. or the nut may move on a screw, as in fig. 22.

85. Almost all kinds of presses, common corkscrew &c. act upon the principle of this mechanical pow

When a screw turns in a wheel, it is called an *endless* screw.

OF FRICTION.

86. In the application of all the mechanical powers, one-third must be allowed to overcome the FRICTION of the surfaces, and the various other obstacles to which all machines are liable.

Obs. 1. If 60 lbs. are required to balance any weight with a mechanical power, 30 lbs. will be wanted, owing to *friction*, to put the machine in motion.

2. Friction is the resistance a moving body meets with from the surface over which it passes; it is of two kinds, the rubbing by friction, and the friction by contact. The former is represented by a locked waggon wheel going down a hill, the second by the wheel touching the ground in its usual motion. The force of friction varies in proportion to the different surfaces in contact; thus a marble passing on a smooth pavement suffers less from friction than it would from gravel, and it would be impeded in its motion still less if it were driven over ice. But the hardest and most polished bodies are not free from inequalities that retard their motion when they act upon one another. The smallest impediment from friction is, when finely polished iron is made to rub on bell-metal, but even these are said to lose about one-eighth of their moving power. The friction between rolling bodies is much less than in those that drag; hence, in certain kinds of wheel-work, the axle is made to move on small wheels, or rollers, in the inner circumference of the nave. These are denominated friction rollers, and are so placed together in a box, and fastened in the nave, that the axle of the carriage may rest upon them, and they turn round their own centres as the wheel continues its motion. Friction rollers do not answer in very heavy machines, as the pressure is apt to wear the naves into notches; but in light and rapid motions they are extremely useful. Larger metal balls, on the same principle, are made use of in moving immense blocks of stone.

3. After a great variety of experiments made with the utmost care and attention, Mr. VINCE deduces the following conclusions, which may be considered as established facts;

Illus. 1. That friction is an uniformly retarding force in hard bodies, not subject to alteration by the velocity, except when the body is covered with woollen cloth, &c. and in that case the friction increases a little with the velocity.

2. Friction increases in a less ratio than the weight o body, being different in different bodies. It is not yet ciently known for any one body, what proportion the inc of friction bears to the increase of weight.

3. The smallest surfa e has the least friction; the w being the same. But the ratio of the friction to the surf not accurately known.

QUESTIONS ON THE MECHANICAL AFFECTI OF MATTER.

What are the *Mechanical powers?*

What are the principal moving powers?

What is the power most easily applied, and whose i most uniform?

What are the three circumstances to be considered in t ing of Mechanical contrivances?

What are the six mechanical powers?

How can the force of a small body be made equal to t a large one?

What is the *lever?*

What is the *fulcrum?*

Where is the *resistance* placed?

On what part of the lever is the *power* applied?

How many kinds of levers are there?

How are they distinguished?

Describe the *first* kind of lever.

What are the uses of this kind of lever?

Draw a diagram, pointing out the *resistance*, *short arm*, *arm*, *fulcrum*, *and power.*

Describe the *second* kind of lever.

Where is the fulcrum, power, &c.?

What are the uses of the second kind of lever?

Describe the *third* kind of lever.

Where is the prop?

Where is the weight, and where the power?

Give a natural illustration of this kind of lever.

What is the *hammer lever?*

What are its principles and uses?

Of what does the *wheel and axis* consist?

How is the power gained by the wheel proportioned t relative diameters of the wheel and axis?

On what mechanical principle does the wheel and axi power?

What is the *pulley?*
What is the use of the fixed pulley?
What proportion of advantage is gained by the moveable pulley?
Explain the reason why a weight can be raised more easily with a pulley than without one.
What is the rule for finding the advantage gained by pulleys?
What is a pair of blocks with a rope called?
What is an *inclined plane?*
Of what every day use is the inclined plane?
How is the velocity with which a body descends on an inclined plane estimated?
Explain the diagram.
On what principle does the *wedge* act?
What is the *screw?*
What is the rule by which the force of a screw and lever is estimated?
Explain the principle of the screw.
Illustrate this principle by an explanation of the figure.
In the application of the mechanical powers, what allowance must be made for *friction?*
What is friction?
What are the kinds of friction?
What are the conclusions of Mr. Vince on this subject?

HYDROSTATICS,

OR THE LAWS OF FLUIDS.

87. HYDROSTATICS treat of the nature, gravity, pressure, and motion of fluids in general, and of the methods of weighing solids in them. And its mechanical practice, called hydraulics, relates particularly to the motion of water through pipes, &c.

88. A fluid is a body, the parts of which yield to any impression, and are easily moved among each other. Fluids are either non-elastic and incompressible, as water, oil, mercury, &c. or elastic and compressible, as air, steam, and the different gases.

Obs. Heat, or motion, is supposed to be the cause of fluidity; *for example, ice,* without heat, is a solid—with heat

becomes a fluid, in *water*—and with more heat, an· a fluid, in *steam*. In the first state, the atoms are fixed in tals—in the second, are thrown into intestine motion—i the third state, are forced asunder with an amazing exp force.

2. Philosophers have usually assumed, that the parti fluids are round and smooth, since they are so easily m among one another. This supposition will account for circumstances belonging to them. If the particles are r there must be vacant spaces between them, in the same ner as there are vacuities between cannon balls that are together; between these balls smaller shot may be p and between these, others still smaller, or gravel, or may be diffused. In a similar manner, a certain quant particles of sugar can be taken up in water without incr the bulk; and when the water has dissolved the suga may be dissolved in it, and yet the bulk remain the same admitting that the particles of water are round, this is accounted for.

3. Others have supposed, that the cause of fluidity mere want of cohesion of the particles of water, oil, &c from this imperfect cohesion, fluids in small quantities under peculiar circumstances, arrange themselves in a s cal manner, and form drops.

89. Fluids are subject to the same laws of gr with solids ; but their want of cohesion occasions peculiarities. The parts of a solid are so connect to form a whole, and their weight is concentrate single point, called the centre of gravity : bu atoms of a fluid gravitate independently of each o

90. Fluids press not only like solids, perpen larly downwards, but also upwards, sideways, a every direction.

Exp. Take a glass tube open at both ends, put a co one end, and immerse the other in water. The fluid w rise far in the tube ; but the moment the cork is taken will rise to a level with the surrounding water; which p the pressure upwards.

91. A fluid kept in an open vessel, or ve will assume a flat surface parallel to the horizon will remain at rest, or rise to a common level.

Exp. If a vessel, *fig.* 23, consists of pipes variously inclined, communicating with each other at *b*, and open at the top, water poured into any one of them will rise to the same level *s f*, in all.

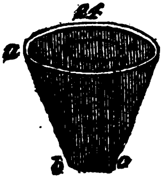
92. The pressure of the same fluid is in proportion to the perpendicular height, and is exerted in every direction; so that all the parts, at the same depth, press each other with equal force in every direction.

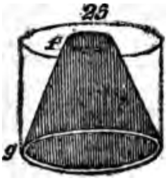
Exp. 1. If a bladder full of air be immersed in water, then the perpendicular pressure is manifest, for the deeper the bladder is immersed, the more will its bulk be contracted.

2. An empty bottle being corked, and by means of a weight, let down a certain depth into the sea, it will be broken, or the cork will be driven into it by the perpendicular pressure.—But a bottle filled with water, wine, &c. may be let down to any depth, without damage, because in this case the internal pressure is equal to the external.

3. It is evident, that the quantities of water in the different pipes, *fig.* 23, whatever be their size, press equally against each other, for if the water be suddenly taken out of the pipes *e*, *s*, or *f*, the surface of the water will instantly descend to a lower level in all the other pipes.

93. The horizontal bottom of a vessel sustains the pressure of a column of the fluid, the base of which is the bottom of the vessel, and the perpendicular height equal to the depth of the fluid.





Exp. 1. In the vessel *a b*, *fig.* 24, the bottom *c b* does not sustain a pressure equal to the quantity of the whole fluid, but only of a column, whose base *c b*, and height *b a*.

2. In the vessel $f\,g$, *fig.* 25, the bottom g sustains a p[illegible] equal to what it would be if the vessel was as wide at [illegible] as the bottom.

94. The pressure of a fluid upon any give[n part] of the bottom or sides of a vessel, is equal [to the] weight of a column of that fluid, having a base e[qual to] that part of the bottom or side, and an altitude [equal] to the perpendicular height of the fluid.

Obs. 1. Hence may be calculated the pressure upo[n] the strength required for dams, cisterns, pipes, &c.

2. The *pressure* of fluids differs from their *gravity* or [weight] in this; the *weight* is according to the *quantity*, but the p[ressure] is according to the *perpendicular height.*

3. From this property also, we ascertain the princi[ple of] spouting fluids. If a hole is bored in the side of an u[pright] pipe filled with water, the fluid will spout out, which [is] the lateral pressure, and this pressure is so much great[er in] proportion as the hole is farther removed from the su[rface;] that is, a hole three feet below the surface of a vessel of [water] will throw out, in the same time, much more water th[an one] only a single foot below.

95. The hydrostatical paradox is this: that [any] quantity of fluid, however small, may be ma[de to] counterpoise any quantity, however large.

Exp. If to the wide vessel $a\ b$, *fig.* 26, a tube $c\ d$ [be at]tached, and water be poured into either of them, it wi[ll stand] at the same height in both. Of course, the small qu[antity in] $c\ d$, balances the large quantity in $a\ b$. But this [is only a] paradox in terms, because the action of the fluid is do[wnward,] not upward.

96. The upper pressure of fluids is shew[n by the] hydrostatical bellows.

Exp. 1. This machine consists of two oval boards [...] in length, and about 14 in width, covered with [...] rise and fall like the common bellows, but without [...] pipe three feet long is fixed to the top board; let [wa]ter run into the bellows to separate the boards, t[...] to the amount of two or three hundred pounds m[...] the upper board; after which, if the pipe be s[...] water, it will, by its upper pressure, sustain a[...] weights.

2. Upon the principle of the upward pressure [...] *metal* may be made to swim in water. Into a [...]

ge a glass tube, open throughout; but by a string hold a piece of lead (1-4 of an inch thick,) fast to the bottom of tube to prevent the water from getting in between the lead the glass. In this situation, if the tube is immersed in the el of water to about three inches depth, the string may be o, but the lead will not fall; it will be kept adhering to it ie upward pressure below it. The lead being about eleven s heavier than water, and the three inches being eleven s the thickness of the lead, is the reason why that depth is l on. Had iron been used, the depth must have been less two inches, because iron is 7 or 8 times heavier than water, and if the plate had been of gold, the depth to which it t have been plunged, would have been nearly 5 inches, use gold is 18 or 19 times heavier than water.

7. A fluid specifically lighter than another fluid float upon its surface. For the lighter fluid will ess powerfully acted upon by the force of gravion than the heavier; whence, the heavier will the lower place.

xp. 1. Let a small and open vessel of wine be placed within arge vessel of water, the wine will ascend.

Let mercury, water, wine, oil, spirits of wine, be put into ial in the order of their specific gravities; they will re- separate.

8. If a body floats on the surface of a fluid specily heavier than itself, it will sink into the fluid t has displaced a portion of fluid equal in weight ie whole solid.

bs. A body, floating on a liquor specifically heavier than , will sink into it, till the immersed part takes up the e of so much fluid as is equal to it in weight. For, in that that part of the surface of the fluid upon which the body , is pressed with the same degree of force, as it would be the space full of the fluid; that is, all the parts of the surare pressed alike, and, therefore, the body, after having into the fluid till it is in equilibrio with it, will remain at

xp. 1. Place a cube of wood in a small jar, exactly filled water; a part of its bulk will be immersed, and will dise a quantity of the water. Take the cube out of the water, put it into a scale, with which an empty vessel in the other stands balanced. Then pour water into that vessel till the librium is restored, and that portion of water will exactly

fill up the jar in which the cube was placed. Conseqı the weight of the water displaced is exactly equal to the of the wood.

2. Let a glass jar, with a weight sufficient to make i in water to about two-thirds of its length, be placed fir large vessel of water, and afterwards in one which is ver wider than the jar, and which has in it a small quan water; the jar will sink to the same depth in both vessel is, till so much of the vessel is under water as is equal i to any quantity of fluid whose weight is equal to that whole vessel.

OF SPECIFIC GRAVITY.

99. By the *specific gravities* of bodies, is the relative weights which equal bulks of diff bodies have in regard to each other.

Obs. 1. Thus a cubic foot of cork is not of equal with a cubic foot of water, or marble, or lead; but the is four times heavier than the cork, the marble 11 tim the lead 45 times; or, in other words, a cubic foot o would weigh as much as 45 of cork, &c. &c.

2. The terms *absolute gravity* and *specific gravity* ve quently occur in physics. The first is what we exp common life by the word *weight*, and signifies the whole power, with which a body presses downward to the Every particle in every substance is heavy; that is, it tendency to fall toward the earth, or is attracted by the Now. the greater the number of particles a substanc the more powerful will be its tendency toward the earth we express the degree of this tendency by certain qua on which we have fixed as standards, by ounces, pound Thus we say, rightly, this stone *weighs* sixteen times as as this ounce. It is very common, however, to say stone is as *heavy* again as this; that pound weight is s times as *heavy* as this ounce; but this, in a physical se improper; the two stones, if they be of the same kin equally *heavy*, bulk for bulk. Their heaviness or gra the same, but their weight is different.

100. It is usual to compare the weight of b with that of water, as it is by weighing them in that their various specific gravities are most co iently found.

Obs. The method of ascertaining the specific gravities of bodies was discovered accidentally by Archimedes. He had been employed by the king of Syracuse to investigate the metals of a golden crown, which he suspected, had been adulterated by the workmen. The philosopher laboured at the problem in vain, till, going one day into the bath, he perceived that the water rose in the bath in proportion to the bulk of his body; he instantly saw that any other substance of equal size would have raised the water just as much, though one of *equal* weight and of *less* bulk could not have produced the same effect. He immediately felt that the solution of the king's question was within his reach, and he was so transported with joy, that he leaped from the bath, and running naked through the streets, cried out, "Ευρηκα, Ευρηκα,"—"*I have found it out,—I have found it out!*" He then got two masses, one of gold and one of silver, each equal in weight to the crown, and having filled a vessel very accurately with water, he first plunged the silver mass into it, and observed the quantity of water that flowed over; he then did the same with the gold, and found that a less quantity had passed over than before. Hence he inferred that, though of equal weight, the bulk of the silver was greater than that of the gold, and that the quantity of water displaced was, in each experiment equal to the bulk of the metal. He next made a like trial with the crown, and found it displaced more water than the gold, and less than the silver, which led him to conclude, that it was neither pure gold, nor pure silver.

101. A body immersed in a fluid will sink to the bottom, if it be heavier than its bulk of the fluid: and if it be suspended in it, it will lose as much of what it weighed in air, as its bulk of the fluid weighs.

102. All bodies equal in bulk, which would sink in fluids, lose equal weights when suspended therein; and unequal bodies of equal weights lose in proportion to their bulks.

Obs. This is the foundation of the whole doctrine of specific gravities. The fluid is a common and uniform measure of weight, with which the other bodies are compared and contrasted.

103. If the same body be successfully placed in fluids of different specific gravities, it will displace more of the lighter than the heavier fluid; and if the weight of

the body be equal to that of the same bulk then it will remain at rest in any part of t

104. The HYDROSTATIC BALANCE, use specific gravities of bodies, differs but lit common balance, (see fig. 27.) It has a hoc tom of one of the scales, on which differer that are to be examined may be hung by

27

Illus. If a body *x* fig. 27, der the scale be first count by weights in the opposite mersed in water, the equili destroyed; then if a weight scale from which the body h the equilibrium, that weigh to the weight of water as la mersed body.

Obs. The instrument use ing the specific gravites of ed the HYDROMETER; a prove or ascertain the strei try the strength of wort, and examine the satu in salt-works. The deeper the hydrometer s the better they are; in worts and brine the c drometers are commonly hollow balls of glass, ball, containing quicksilver at the bottom, and at the top. The tube or stem is graduated, th which it sinks may be known.

105. The specific gravity of all bodies water may be found, first by weighing th then in water, and dividing the weight loss of weight in the water.

Exam. A guinea weighs 129 grains in air; b ed in water it loses 7 1-4 grains, which shews, t of water of equal bulk with the guinea, weigh divide 129 by 7 1-4, or 7.25, and the quotient which proves the guinea to be 17.793 times h bulk of water.

Corol. 1. We hence easily deduce the metho the specific gravities of all bodies, taking ra standard, a cubic foot of which being unifo weigh 1000 avoirdupois ounces.

The weight which a body loses in a fluid, weight as the specific gravity of the fluid is to th

If a guinea weigh in air 129 grains, and in being immersed in water lose 7 1-4 of its weight, the proportion will be 7 1-4; 129 : : 1000 to the specific gravity of a guinea. By this method, the specific gravities of all bodies that sink in water may be found and expressed in a table.

2. Hence, if different bodies be weighed in the same fluid, their specific gravities will be as their whole weights directly, and as the weights lost inversely.

If a body to be examined consist of small fragments, they may be put into a small bucket and weighed; and then if from the weight of the bucket and body in the fluid, we subtract the weight of the bucket in the fluid, there remains the weight of the body in the fluid.

3. If the same body be weighed in different fluids, the specific gravity of the fluids will be as the weights lost.

The loss of weight sustained by a glass ball in water and milk is respectively 803 and 831 grains, therefore the specific gravity of water is to that of milk as 803 : 831, that is, as 1.000 : 1.034. By the same method, the specific gravity of water, is to that of spirits of wine as 1.000 to 857.

SPECIFIC GRAVITIES OF VARIOUS BODIES.

Platina	23.000	Milk	1.034
Fine gold	19.640	Box-wood	1.030
Mercury	14.019	Rain water	1.000
Lead	11.325	Oil	.920
Fine silver	11.091	Ice	.908
Copper	9.000	Brandy	.820
Iron	7.645	Living men	.891
Diamond	3.517	Ash	.800
Marble	2.705	Beech	.700
Glass	3.000	Elm	.600
Flint	2.570	Fir	.550
Chalk	1.793	Cork	.240
Coal	1.250	Common air	.00112
Mahogany	1.063	Hydrogen gas	.000105

Obs. 1. The above table shews the specific weights of the various substances contained in it, and the absolute weight of a cubic foot of each body is ascertained in avoirdupois ounces, by multiplying the number opposite to it by 1000, the weight of a cubic foot of water, thus the weight of a cubic foot of mercury is 14019 ounces avoirdupois, or 876 lbs.

2. If the weight of a body be known in avoirdupois oun its weight in Troy ounces will be found in multiplying it .91 145. And if the weight be given in Troy ounces, it wi found in multiplying it into 1.0971.

3. Mr. Robertson, late librarian to the Royal Society vestigated the specific gravity of living men, in order to kn what quantity of wood would be sufficient to keep a man af in water, supposing that most men were specifically hea than river water, but the contrary appeared to be the from trials which he made upon ten different persons, wh mean specific gravity was, as expressed in the table, 0.891 about 1-9th less than common water. If, however, as in s cases, they are heavier, and, indeed, as the weight of t heads out of the water would generally sink them, it ma worth while to be able to ascertain the weight of cork ficient to buoy up any man.

If, then, as an example, the absolute weight of a mi sized man be 135 pounds, the weight of two cubic fee water be 123 lbs the specific gravity of cork be *one fourth* of of water, and the weight of the cork required be represe by *w*; then the x lbs. of cork, when wholly immersed, displace 4 x lbs. of water; and the weight of the person the cork, 135-|-x, must of course be equal to that of the ter displaced by both 123-|-4x, in order that the person swim as required. Hence we have the following equat 123-|-4x, = 135 -|-x. Consequently, 123 -|- 3x = Therefore 3x=135—123=12 Whence we find x=4. pounds of cork, therefore, will keep such a person from s ing, so that he may remain with his head completely al water.

HYDRAULICS.

106. The science of Hydraulics teaches how estimate the velocity and force of fluids in mot Upon the principle of this science all machines wo ed by water are constructed, as engines, mills, pum fountains, &c.

107. Water can be set in motion only by its own vity; as when it is allowed to descend from a highe

a lower level: by an increased pressure of the air, or by removing the pressure of the atmosphere, it will rise above its natural level.

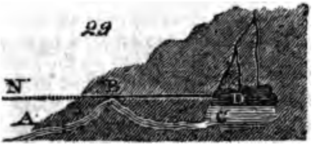
Obs. 1. In the former case it will seek the lowest situation; in the latter, it may be forced almost to any height.

2. Any part of a fluid at rest presses, and is pressed, equally in all directions. For each particle is disposed to give way on the slightest difference of pressure: consequently, it presses equally in all directions. Hence the lateral pressure of a fluid is equal to the perpendicular pressure. *And this is one of the most extraordinary properties of fluids*, and can be conceived to arise only from the extreme facility with which the component particles move among each other.

108. A Syphon is a bent tube, one of whose legs is longer than the other. The shorter leg is immersed in the liquor to be drawn off, and the pressure of the air being taken from that part of the surface of the liquor within the tube, the liquor will rise above its natural level in the vessel, and will flow off through the longer leg.

Obs. 1. A syphon is used by filling it with water or some other fluid, then stopping both ends with the finger, and in this state immersing it in the vessel. The fingers being removed the water flows out of the longer leg, by its own gravity, and afterwards by the pressure of the atmosphere on the liquor in the vessel.

2. Intermitting springs are caused by the principle of the syphon, the water flowing through the natural pipes or syphons from reservoirs of water in the earth, which fill only at certain seasons.



Illus. If C be a cavern in a mountain, receiving water which escapes by the channel A B C, it is evident that it will flow only when it rises in D to the level N. B. D.

109. The velocity with which water spouts out at a hole in a side or bottom of a vessel, is in proportion to *the square root* of the distance from the hole below the

surface of the water ; and the pressure of wat
the sides of a vessel is as the *square* of the d

Exam. 1. If at the distance of one foot from th
the velocity is 1, another hole four feet from the surf
give the velocity of 2, and at 9 feet deep there woul
locity of 3, 2 and 3 being the square root of 4 and 9.

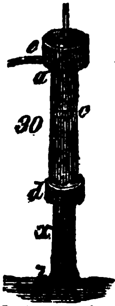
2. If a vessel be three feet deep and filled with
pressure upon the sides of the first foot will be 1,
and second will be 4, and on the whole side it will b

110. Fluids may be conveyed over hills an
in bent pipes, to any height which is not gre
the level of the spring from whence they fl

Obs. All water finds its own level. But from ig
this single principle, the ancients constructed vast
across valleys to convey water across them ; wh
moderns effect the same purpose by means of wood
iron, or stone pipes.

111. Fountains are formed upon the sam
ple : if, near the bottom of any vessel, a s
bending upwards be fastened, the water w
out through the pipe, and rises nearly as hi
surface of the water in the vessel.

112. The Common Pump consists of a p
at both ends, in which is worked a moveabl
that fits the bore exactly, and is provided wit



30

Illus. Fig. 30 is the representation of
pump; *a b* is called the *barrel* which c
piston ; b d the pipe communicating wit
ter below. At the junction of these
there is a fixed *valve* or little trap-door
fig.) *d* opening *upwards.*

The mode of operation is as follows :
is fixed in water, and the piston *c h* is t
down upon the valve *d*. In drawing up
from *d* to *c*, a vacuum of air is form
space, consequently, the air in the rest
from *d* to *b* will force its way through
d, and fill the part which had been exh
will therefore, be rarer than before
being equivalent to the pressure of the atmosphere
water at *d*, in which the pump is immersed, the

e forced or pressed up into the pipe as far as x, until the upper air within be as dense as before.

Upon depressing the piston a second time, the same effect produced, till at length the water is forced, by the pressure f the air b, up into the pipe above d. When the piston now escends, it is forced into the water, which, as it cannot reass through the valve d, must, therefore, rise above the isten by passing through its *valve* c; and when the piston is ext raised, all the water above it will be lifted up, and will un off by the pipe.

113. The FORCING PUMP consists of a barrel, a lunger, and two fixed valves, that should be air ight, and so disposed as to let the water freely rise, ut prevent its return.

Illus. In fig. 31, a b is the barrel: c a solid piston or plunger; at d is one valve opening upwards, the other is the branching pipe s. When the piston is first moved upwards in the barrel, the air below will be rarefied and the water rise up in b: and by repeated strokes of the pistons, the water will be brought up between the fixed valve d and s.

It cannot, therefore, descend by d, but must make its way through the upper valve at s, which shuts the moment the waiter has passed by its own weight.

v is a strong air vessel closed at the top by a small pipe, that reaches nearly to the bottom. The water is forced along the rising pipe s, gets into the vessel, and rises above the lower part of the pipe. The air which is above the water in the vessel being confined, and condensed into a maller bulk than its natural space, presses by its elasticity pon the surface of the water, and forces it violently up the ipe in a continual stream. This is the principle of the EN-INE for extinguishing fires.

114. The water is raised by pumps owing to the lasticity or pressure of the atmosphere; it can be aised only 33 feet, because the force of the atmoshere is equal only to a column of water 33 feet high.

Obs. 1. The forcing pump is unlimited in regard to the eight to which it can throw water. The air-vessel added to he forcing pump, gives the water a more equable stream.

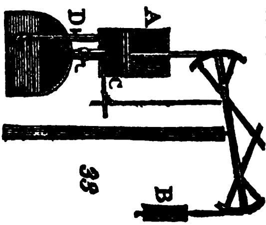
2. A constant stream may be produced by *two* bar
pistons moving up and down alternately, as is th
many pumps.

115. The STEAM ENGINE consists of a lar
der or barrel, in which is fitted a solid piston
of the forcing pump. Steam is thus supplie
large boiler, which, in forcing up the piston, i
opens a valve, through which cold water rushe
principle of the common pump.

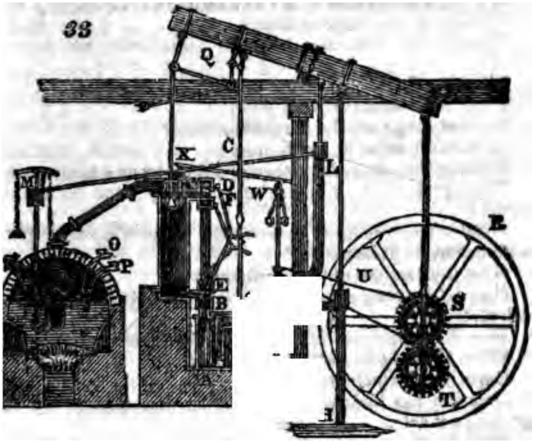
Other steam is then introduced above th
which forces it down again, and drives the w
of the pipe with immense force.

Steam then raises the piston again, and agai
it fall, and by this alternate motion the grand
rations are performed. The action of th
moves up and down a large beam, and th
communicates to other machinery, the powe
or 200 horses!

Obs. 1. The power of some of the steam engines c
ed by Messrs. Boulton and Watt, is thus described,
by actual experiment. An engine having a cylinde
ches in diameter, and making 17 double strokes pe
performs the work of 40 horses, working night an
which 3 relays, or 120 horses must be kept, and bur
pounds of Staffordshire coal per day. A cylinder o
es, making 25 strokes, 4 feet each, per minute, per
work of 12 horses working constantly, and burns 37
of coals per day. These engines will raise more th
cubic feet of water, 24 feet high, for every 100 weig
pit coal consumed by them.



2. This cut represent
mon steam engine. A i
cylinder, containing t
which works up and d
moves the beam and t
ance B. The steam p
the boiler, at the pipe I
cylinder under the pist
it, and the jet at C th
water, condenses the st
allows the piston to fa



3. This is Watt's improved engine. The principle is the me as the preceding, but the economy is greater. The eam which is below the piston escapes into the condenser A, the cock B, which is opened by the rod C, and at the same ne the steam is admitted by the cock D into the upper part the cylinder; when the piston had descended, the cocks E id F act in a similar manner in letting out the steam from ove, and admitting it below the piston. The jet is suppli- l by the water of the cistern G, which is pumped up at H, om a reservoir: it is drawn out, together with the air that extricated from it, by the air pump I, which throws it into e cistern K, whence the pump L raises it to the cistern M; id it enters the boilers through a valve which opens when- ver the float W descends below its proper place. The pipes and P serve also to ascertain the quantity of water in the iler. The piston rod is confined to a motion nearly rectili- ear by the frame Q. The fly-wheel R is turned by the sun id planet wheel S T, and the strap U turns the centrifugal gulator W, which governs the supply of steam by the valve stop cock X.

4. Steam engines have been advantageously applied lately impel vessels in smooth waters, as rivers, canals, &c.

QUESTIONS ON HYDROSTATICS.

Of what do *hydrostatics* treat?

What is the difference between *hydrostatics* and *hydr lics?*

What is a fluid?

What is the cause of fluidity?

Of what shape are the particles of fluids?

In what direction do fluids press?

Ilustrate the *upward* pressure of a fluid by an experimen

What governs the pressure of a fluid upon the bottom vessel?

What relation is there between the perpendicular heigh a fluid, and its pressure?

Give illustrations of these principles.

How is the pressure of the fluid on the bottom of the v calculated?

How does the *pressure* of a fluid differ from its gravity?

What is the *hydrostatical paradox?*

Explain its principle.

Describe the hydrostatical bellows, and explain on w principle it acts.

Explain the manner in which lead may be made to s upon water.

Explain the reason why a body specifically heavier water will not sink to any depth in that fluid.

Describe some experiment to illustrate this doctrine.

What is meant by the *specific gravities* of bodies?

What is the difference between *absolute* and *specific* vity?

Describe the method by which the specific gravity of a l is taken, and explain the principle.

What is the construction of the *hydrostatic balance?*

Explain its use.

Explain the action of the hygrometer.

What is the rule for finding the specific gravity of a l after weighing it in air and in water?

How is the specific gravity of a fluid taken?

What were the results of Mr. Robertson's experiment the specific gravities of men?

What does the science of *hydraulics* teach?

What useful machines are constituted on the principl this science?

What are the different ways in which water can be s motion?

What are the directions in which fluids press?

In what proportion is the lateral to the *perpendicular* pressure of a fluid?

What is a *syphon*?

Illustrate the principles of the syphon.

How are *intermitting* springs caused?

How is the velocity with which water spouts out at a hole in the side of a vessel calculated?

Give an example.

On what principle may water be conveyed over hills in bent pipes?

On what principles are fountains formed?

Describe the *common pump*.

What are the different parts of a forcing pump, and the principles upon which it acts?

How high can water be raised by the common pump, and on what principle?

Describe the steam engine, and give an example of its powers.

PNEUMATICS.

116. The science of Pneumatics treats of the mechanical properties of elastic or aeriform fluids; such as their *weight*, *density*, *compressibility*, and *elasticity*.

117. The air in which we live surrounds the earth, and extends to a considerable height above it. The air, together with the clouds and vapours that float in it, is called the atmosphere.

Obs. 1. This atmosphere is necessary to animal and vegetable life, and to combustion: it is a very heterogeneous mixture, being filled with vapours of all kinds. It consists however of two great principles called *oxygen* in 28 parts, and *azote* in 72 parts, of 100.

2. The height to which the atmosphere extends has never been ascertained; but at a greater height than 45 miles, it ceases to reflect the rays of light from the sun.

118. The air is not visible, because it is perfectly transparent: but it may be felt on moving the hand in it, or when it moves and produces what we call *wind*.

Exp. 1. The existence of the air may be ascertained by swinging the hand edgeways swiftly up and down, which gives the idea of separating the parts of some resisting medium.

2. Any swift motion, as of a stick, or whip, or fan, proves the existence of air as a resisting medium.

119. Air is 900 times lighter than water; but the whole atmosphere presses on all sides like other fluids, upon whatever is immersed in it, and in proportion to the depths.

Exam. 1. It is known that the pressure of the atmosphere is less upon a mountain than in the plain or valley beneath.

2. The pressure of the air may be thus shewn: cover a wine glass completely filled with water, or wine, with a piece of writing paper; then place the palm of the hand over the paper, so as to hold it tight and accurately even. The glass may then be turned upside down, and the hand removed without the water running out. The pressure of the air upon the paper sustains the weight of the water.

3. It is the pressure of the atmosphere which sustains the mercury in the barometer tube. On ascending a mountain the mercury sinks. This shows that a part of the pressure is taken off.

On the surface of the earth the water boils at 212 degrees; on Mount Blanc, it boils at 187 degrees. These and many other experiments shew, the higher we ascend from the surface of the earth, the less is the atmospheric pressure.

120. The air can be compressed into a less space than it naturally occupies.

Exp. 1. Take a glass tube open only at one end, and it is of course full of air. Plunge the open end into a bowl of water, and you see the water rises an inch or so in the tube; the air, therefore, which before filled the whole length of the tube, is compressed by the water into a smaller space.

2. Take a cork swimming on a basin of water, cover it with an empty glass tumbler, which force down through the water. The cork evidently shews, that the surface of the water within the tumbler is not on a level with the surface without. This experiment proves that air is a body which prevents water from occupying the same space with itself; it proves also that the air is compressible, because the water does not ascend in the glass.

121. The air is of an elastic or expanding nature and the force of the spring is equal to what is common-

called its weight. The spring, however, operates in l directions,and is as powerful in small as large bulks.

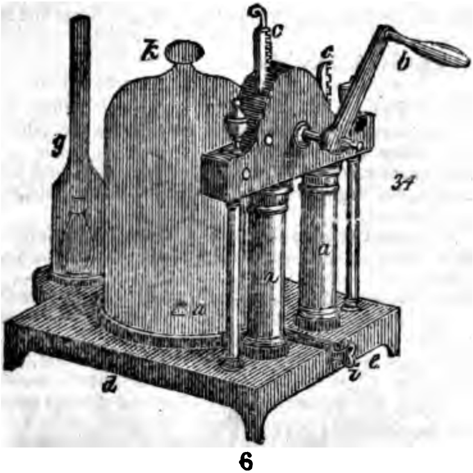
Exp. 1. Fill a bladder with air by blowing into it, and in is state the bladder is highly elastic; it proves also that air as much a substance as wood or metal, for no force can, ithout breaking the bladder, bring the sides together, ough the parts of an empty bladder may be squeezed into ıy shape.

2. Open a pair of common bellows in the usual manner, ıd then stop the nozzle securely, and no force can bring the ırts together, without first unstopping the nozzle, or bursting ıe leather: another proof that air is a solid substance.

122. When air is in motion it constitutes what we ıll *wind;* which is nothing more than a current of r, varying its force, according to the velocity with hich it flows.

123. AIR-PUMPS are machines made for exhausting the air from certain glass vessels adapted to the urpose of experiments on air.

Illus. Fig. 34, represents one of the most convenient airumps.



a a two brass barrels each containing a piston, with a valve opening upwards. The pistons are worked by means of the winch *b*, which moves them up and down alternately. On the wooden frame *d e*, there is a brass plate *g*, ground perfectly flat and even; and also a brass tube, communicating with the two cylinders beneath, and the cock *i*, and opening into the centre of the brass plate at *a*.

k is the glass receiver which is to be exhausted of air, and is made to fit very accurately on the brass plate, particularly when a wet piece of leather is laid between them.

Having shut the cock *i*, the pistons are worked up and down, and the air is drawn from the glass receiver through the pipe, and is suffered to escape; when the piston is forced down the air rises through it, because the valve opens upwards but it is prevented from returning into the vessel for the same reason. The air being gradually exhausted from the receiver, it becomes immoveably fixed by the pressure of the surrounding atmosphere.

Upon opening the cock *i*, the air rushes again violently, and with a noise into the receiver.

124. The Air-pump is the grand machine by which experiments on air are made. By its means the following important properties of air are demonstrated

1. *The air has weight.*

Exp. 1. The air being exhausted by an air-pump, from a glass receiver, the receiver will be held fast by the pressure of the external air.

2. If a small receiver be placed under a larger, and both be exhausted, the larger will be held fast, while the smaller will be easily moved.

3. If the hand be placed upon a small open vessel, in such a manner as to close its upper orifice, it will be held down with great force.

4. The upper orifice of an open receiver being closely covered with a piece of bladder, upon exhausting the receiver, the bladder will be pressed till it burst.

5. Let the air be exhausted from a glass vessel, and by means of a cock, let the vessel be kept exhausted; weigh the vessel whilst it is exhausted, and when the air is to be re-admitted, the difference is the weight of so much air as the vessel contains; which difference will be about 324 grains for a ...sand cubic inches.

Into the receiver *a*, fig. 35, put a small vessel of quicksilver, and through the collar of leather as at *b*, suspend a glass tube, closed at the upper end, over the quicksilver. The apparatus thus situated is to be placed on the brass plate of the air-pump, and the air completely exhausted from the receiver, the tube is then to be let down into the quicksilver, which will not rise in it as long as the receiver continues empty; but as soon as the air is re-admitted, all the surface of the quicksilver is pressed upon by the air, except that portion which lies above the orifice of the tube; it will therefore *rise in the tube*, until the weight of the elevated quicksilver presses as forcibly on that part of it which lies beneath the tube, as the weight of the air does on every other equal portion without the tube.

7. A common experiment among boys is on the same principle. Take a piece of thick spongy soal leather, cut it into a circular form, and through the centre pass a string; wet it thoroughly, and place it flat on a smooth surface; then try to pull it up in a perpendicular line A vacuum is formed in the centre, while the edges are pressed down by the weight of the atmosphere. In this way, a smooth stone of many pounds weight may be lifted.

Obs. 1. Hence the pressure of the atmosphere on or near the surface of the earth is known; the weight of any column of air being equal to the weight of the column of mercury, of the same diameter, supported in the barometer. And, since the height of this column varies with the weight of the atmosphere, (between 28 and 31 inches, equal to 23 feet of water,) the varieties in the weight of the atmosphere are known by the BAROMETER. The most usual altitude of the barometer, in London, is between 28 and 31 inches, but it is seldom seen below 28 1-2 or 30 1-2 inches.

2. In calm weather, when it is inclined to rain, the mercury is commonly low. In serene settled weather, the mercury is generally high. During very great winds, though unaccompanied with rain, the mercury sinks lowest of all.

2. *The air presses equally in all directions.*

Exp. 1. If a glass vessel be filled with water, and covered with a loose piece of paper, on inverting the glass, the water will be kept from falling by the upward pressure of the air.

2. If a vessel be perforated in small holes at the bottom, but closed at the top, the upward pressure of the air will keep the

water within the vessel; as will appear by successive
ping and unstopping a small hole in the top of the vess
drawing beer from an air-tight cask.

3. Two brass hemispherical cups put close togethe:
the air between them is exhausted, will be pressed t
with considerable force.

4. A syringe being fastened to a plate of lead, and th
of the syringe being drawn upwards with one hand, wl
lead is held in the other, the air, by its upward pressu
drive back the syringe upon the piston; whereas, if the
syringe be hung in a receiver, and the air being exl
the syringe and lead will descend; but upon re-admit
air, they will again be driven upwards.

5. If a thin glass vessel, whose aperture is closed, be
under the receiver of an air-pump, and the air ex
from the receiver, the vessel will be broken by the pre
air within.

3. *The air is an elastic fluid, or capable of co
sion or expansion.*

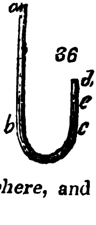
Exp. 1. A blown bladder, pressed with the hand,
turn into the form which it had before the pressure.

2. An empty bladder put under a receiver, when th
nal air is exhausted, becomes extended by the elasticit
internal air.

3. A bladder suspended within the receiver, with
weight hanging from it, which touches the bottom, w
external air is exhausted, by the expansion of the :
air, will raise the weight.

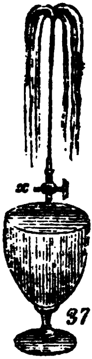
4. The bladder being put into a box, and a weight l
on the lid, the lid, on exhausting the air, will be lifted i

5. If a tube, closed at one end, be inserted at its op
in a vessel of water, the fluid in the tube will not rise
level of the water in the vessel, being resisted by the
force of the air within the tube. On this principle the
bell is formed.



6. This bent tube *a b c d*, fig. 36, is open
ends. I have poured mercury into the tul
to rise in both sides of the tube *c* and *b*; t
from *c d*, is full of air at the common density
up *d*, so as to make it air tight, and pour n
into *a*, so that the column of mercury *a b* s
equal in length to the height at which it stan
barometer at the time. The air in the sho
will now be compressed by the weight of the
phere, and also with an additional weight of a col

mercury; and the mercury in the shorter leg will be risen to *e*, and *e e* is the only half of *d c*; that is, the pressure of a double atmosphere compresses the air to half the space which it naturally occupies. If another equal column of mercury were added to the length *a b*, the air in *d c* would be reduced into one fourth the space that it formerly occupied.



37

7. *a* fig. 37, is a strong copper vessel, having a tube that screws into the neck of it, so as to be air-tight, and long enough as nearly to reach the bottom; *x* is the handle of a stop-cock. Having poured some water into the vessel, and screwed in the tube, the condensing syringe is to be adapted, and the air condensed. The stop-cock is to be shut, while the syringe is unscrewed, then, on opening the cock, the air, by its great density acting upon the water in the vessel, will force it out in a jet to a considerable height. This is called the artificial fountain.

4. *The elastic spring of the air is equivalent to the force which compresses it.*

Exp. Let the air be exhausted from an open tube, whose lower part is inserted in a vessel containing a small quantity of mercury, and let the air within the vessel be prevented from escaping; this air, by its elasticity, will force the mercury up the tube nearly to the height to which it would be raised by the pressure of the atmosphere.

Obs. If the spring with which the air endeavours to expand itself when it is compressed, were less than the compressing force, it would yield still farther to that force; if it were greater, it would not have yielded so far. Therefore, when any force has compressed the air so that it remains at rest, the spring of the air rising from its elasticity must be equal to the pressure.

5. *The elasticity of the air is increased by heat.*

Exp. 1. To the bottom of a hollow glass ball, let an open bended tube be affixed. Let the lower part of the bended tube and part of the ball be filled with mercury; the external surface will be pressed by the weight of the atmosphere; and the internal surface will be equally pressed by

6 *

the spring of the air enclosed within the vessel. If the ball b immersed in boiling water, the increased elasticity of the in cluded air will raise the mercury in the small tube. The sam may be shewn by immersing in boiling water, a tube, closed a one end, into which a small quantity of mercury has been ad mitted, inclosing a portion of air within the tube.

2. The wind is no other than the motion of the air upon th surface of the globe. The principal cause of wind, is, tha the atmosphere becomes heated over one part of the eart more than over another. For, in this case, the warmer a being rarefied, becomes specifically lighter than the rest; it therefore overpoised by it, and raised upwards, the upper par of it diffusing themselves every way over the top of the atmo phere; while the neighbouring inferior air, rushes in from a parts at the bottom; which it continues to do until the equ librium is restored. Upon this principle it is, that most win may be accounted for.

3. Fill a large dish with cold water; into the middle of th put a water-plate, filled with warm water. The first wi represent the ocean; and the other an island, rarefying th air above it. Blow out a wax candle, and if the air be stil on applying it successively to every side of the dish, the smok will be seen to move towards the plate. Again, if the ambie water be warmed, and the plate filled with cold water, l the smoking wick of the candle be held over the plate, and th contrary will happen.

6. *The pressure of the atmosphere varies at diff rent altitudes.*

Exp. Put a glass tube, open at both ends, through a cor into a large phial containing a small quantity of coloured wa ter; let the lower end of the tube be in the water, and let th cork and tube be closely cemented to the neck of the bott Then blow through the tube, till the quantity of the air with in the phial is so increased, that the water will rise above th neck of the phial. Let this phial be placed in a vessel of san to keep the air within of the same temperature; the wat will stand at different heights in the tube, according to th elevation of the place where it is placed; from whence is ap pears, that the pressure of the atmosphere varies at differe altitudes.

Corol. Hence the proportion of the specific gravity of a to that of water may be determined. If the difference height of the two places where the above experiment made be 54 feet, and that difference cause a difference

3-4 of an inch in the height of the water; it follows, that a column of water of 3-4 of an inch, or 1-16th of a foot, is equiponderant to a column of air of 54 feet, having the same base; therefore, the gravity of air to that of water, is 54 to 1-16th, or 864 to 1. In ascending the mountain of Snowden, in Wales, which is 3720 feet perpendicular height, it was found, that the barometer sunk 3 inches and 8-10ths.

PNEUMATIC INSTRUMENTS.

125. The Syringe is a hollow tube with a small orifice at one end: at the other end is inserted a solid cylinder, so exactly fitted to the tube that no air can pass along its sides, and a fixed handle to the solid cylinder. If that end of this instrument which has the smaller orifice, be drawn back, a vacuum will be produced within the syringe; and the pressure of the atmosphere on the surface of the water, meeting with no opposite pressure, will force the water into the tube, from whence it may be forcibly expelled by pushing down the piston.

126. The Condenser is used to force air into any vessel; it is a syringe, having a solid piston, and a valve in the lower part of its barrel which opens downwards. By thrusting down the piston the air is forced through the valve, which is afterwards held close by the elasticity of the condensed air. When the piston is lifted up, a vacuum is produced, till it is raised above a small hole in the barrel, when the air rushes in, and is again discharged through the valve.

127. The Air-Gun, is an instrument, in the form of a gun, by which a quantity of condensed air is suddenly set free, and drives a ball through the barrel with great force.

128. The Barometer is a very useful instrument for determining the variations of the weather.

Exp. 1. If a glass tube of about 32 or 33 inches long, hermetically sealed at one end, be filled with mercury, and then inverted into a basin of the same fluid, the mercury in the tube will stand at an altitude above the surface of that in the basin

between 28 and 31 inches. A tube thus filled, and graduated from 28 to 31 inches, is called a barometer. Hence, as a cubic inch of water weighs 253.18 grains Troy, a cubic inch of air weighs 0.286 grains, and if mercury be 14 times heavier than water, the specific gravity of air is to that of mercury as o 886X14=12390.

2. Now the mercury in the barometer tube will subside, till the column be equivalent to the weight of the external air on the surface of the mercury in the basin, and is therefore a true criterion to measure that weight, and chiefly directed to that purpose, in order to foretel the changes in the weather.

Obs. 1. If each inch in the scale of variation be divided into ten equal parts, marked 1, 2, 3, increasing upwards, and a *vernier* whose length is 1 1-10th of an inch, be likewise divided into ten equal parts, increasing downwards, and so placed as to slide along the graduated scale of the barometer, the altitude of the mercury in the tube, above the surface of that in the basin, may be found, in inches and hundredth parts of an inch, by this *vernier*. If the surface of the mercury in the tube does not exactly coincide with a division in the scale of variation, place the index of the *vernier* even with this surface, and observing where a division of the *vernier* exactly coincides with one of the scale, the figure in the *vernier* will shew what hundredth parts of an inch are to be added to the tenth immediately below the index.

2. If the atmosphere were homogeneous, its altitude would be easily found. For when the mercury stood at 29 1-2 inches, the density of the air being to that of mercury as 1 to 12390, consequently, the altitude of an homogeneous atmosphere would be equal to 12390X29 1-2=5.77 miles.

3. The barometer has been applied to the measuring of the *heights of towers*, *mountains*, &c. Since 12390 inches of air near the surface of the earth, are equal to one inch of mercury, 1239 inches, or about 103 feet of air, must be equal to 1-10th of an inch of mercury. Therefore, if a barometer be carried up any great eminence, the mercury will descend 1-10th of an inch for every 103 feet that the barometer ascends.

129. The THERMOMETER is an instrument calculated for measuring the temperature of the air, and bodies, and is usually a cylindrical glass tube, containing spirits of wine, mercury, &c. which fluids are found to swell and occupy different portions of the tube at different temperatures.

Obs. The bulb, and part of the tube is filled with quicksilver; this contracts and expands as the instrument is exposed to more or less heat, and consequently the temperature of contiguous bodies is shown by its rise and fall in the tube, which is measured by a scale.

2. The Thermometer chiefly used in Great Britain, is that constructed by Fahrenheit; in which there are 180 divisions between the freezing point being reckoned 32° above zero, or the commencement of the scale; consequently the boiling water point is 212°

3. The scale on Reaumur's thermometer, which is principally used on the Continent, begins at the freezing point, and proceeds both ways, from 0 to zero. From freezing to boiling water are 80 degrees.

4. Since the thermometers of Fahrenheit and Reaumur are those mostly in use, it will be often found convenient to be able readily to convert the degrees on Fahrenheit's scale into those of Reaumur, and vice versa: and as one degree on Reaumur's scale is equal to 2.25°, or to 90-4th of Fahrenheit; and as the former scale places the freezing point at zero, and the latter places it as 32; the following canons will reduce the degrees on the one to the corresponding one on the other.

Obs. To convert the degrees of Fahrenheit into those of Reaumur; $\frac{\overline{F-32} \times 4}{9} = R$: thus the 167° of Fahrenheit answers to the 60° of Reaumur.

To convert the degrees of Reaumur to those of Fahrenheit: $\frac{R \times 9}{4} + 32 = F$.

Thus the 40° of Reaumur answers to the 122° of Fahrenheit.

5. Mr. Wedgewood contrived a thermometer for measuring higher degrees of heat, by means of a property of argillaceous bodies, viz. the diminution of their bulk by fire. This diminution commences in a dull red heat, and proceeds regularly as the heat increases, till the clay becomes vitrified.

Each degree of Wedgewood's thermometer answers to 130 degrees of Fahrenheit; and he begins his scale from 1077 o Fahrenheit.

	Degrees of Fahrenheit.	Degrees of Wedgwood.
Cast iron melts - -	21877	160
Fine gold melts - -	5237	32
Fine silver melts - -	4717	28
MERCURY BOILS - -	600	
Cow's milk boils - -	213	
WATER BOILS - -	212	
Heat of the human body -	92 to 99	
WATER FREEZES and snow melts	32	
Milk freezes - -	30	
Strong wine freezes -	20	
MERCURY FREEZES -	—39 or 40.	

130. The HYGROMETER is an instrument for measuring the degrees of moisture in the air; of which there are various kinds; for whatever contracts and expands by the moisture and dryness of the atmosphere, is capable of being formed into a hygrometer. Such are most kinds of wood; catgut, twisted cord; the beard of wild oats; the weather house, &c.

QUESTIONS ON PNEUMATICS.

What is the object of the science of pneumatics?

What is the *atmosphere?*

To what height does the atmosphere extend?

How may the existence of the air be ascertained?

How much lighter is air than water?

How is the pressure of the air shown?

How is it known that the pressure of the atmosphere decreases upwards?

What is said concerning the elasticity, or expanding nature of air?

How is this illustrated?

What is *wind?*

What is an *air-pump?*

How is it demonstrated that the air has weight?

What is said concerning the variation of the mercury in the *barometer* tube?

What experiments show that the air presses equally in all directions?

How is it proved that the air is elastic? mention the *experiments.*

What is said of the force of the elastic spring of air?

What experiments demonstrate that the elasticity of air is increased by heat?

What simple experiment proves that the pressure of the atmosphere varies at different altitudes?

What is a *syringe?*

Describe its action.

Describe the *condenser.*

How is the air-gun constructed?

What is the use of the *barometer?*

How is it constructed?

What is the rule for measuring altitudes with the barometer?

What is the *thermometer?*

On what principle does it show the temperature of air, and of other bodies?

What thermometers are chiefly used in England and in this country?

How is it graduated?

What are the freezing and boiling points?

What is the hygrometer?

Of what substance may it be constructed?

ACOUSTICS.

131. ACOUSTICS is the science which treats of the nature, phenomena, and laws, of the sense of sound. It extends to the theory of musical concord and harmony, and is therefore, a valuable and interesting science.

132. Sound is considered as arising from vibrations in the air, communicated to it by vibrations of the sounding body, acting in pulsations or concentric waves, like the surface of water when a stone is thrown into it.

Obs. If when a piece of artillery is fired at a distance, some dust floating in the air, or a cobweb be closely inspected, it will be seen to be agitated at the instant when the report is heard. This proves that the vibrations of the air travel with the same velocity that sound does, and that it is by means of these vibrations striking on the ear-drum that sounds are conveyed.

133. A sonorous body, whilst sounding, is unquestionably in a state of vibration, and the air, by similar

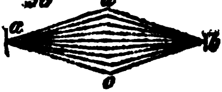
vibrations, communicates and propagates these vibrations.

134. The chief causes of the variety of sounds, are, *First*, the greater or less frequency of the vibration.
Secondly, the quantity or force of the vibrating materials.
And, *Thirdly*, the greater or less simplicity of the sounds.
Hence arise the height, the strength, and the modification of sounds.

Obs. When sounds are equally acute, they are said to have the same pitch; but when they differ in acuteness, that sound which is shriller is said to be acute, or to have a higher pitch; and that which is less shrill, is said to be graver, or to have a lower pitch, or a deeper tone. A difference in pitch, forms the chief character by which musical sounds are distinguished from each other, and is the foundation of their use in music.

135. The vibrations of a sounding body, continue for a longer or shorter time, according as the body is more or less elastic, or as it is thicker or thinner.

38



Exam. 1. When a string of uniform shape and quality is stretched between, and fixed to, two steady pins, as *a b*, fig. 38, if it be drawn out of its natural or quiescent position *a b*, into the situation *a c b*, and then be let go, it will in consequence of its elasticity, not only come back to its position *a b*, but it will go beyond it, to the situation *a d b*, or nearly as far from *a b*, as *a c b* was on the other side. All the motion one way, is called one vibration: after this, the string will go again nearly as far as *c*, making a second vibration; then nearly as far as *d*, making a third vibration, and so on; diminishing the extent of its vibrations gradually, until it settles again in its original position *a b*.

Obs. 1. During the whole of these vibrations, the string will forcibly act on the air and produce corresponding vibrations in it, which, reaching and entering the ear, produce on the nerves therein, the sense of sound.

2. The following experiment indicates a curious accordance of vibration, and proves that the air re-acts in the exact law of the original vibration.

39

Exp. If you divide a string as *a b*, fig. 39, into three equal parts, *ab*, *bc*, *cd*, by placing dots at *c* and *b*; place a bridge like a violin bridge, at b, also place light bodies, such as small bits of paper

at *c*, and other places of the part *b d*. Then draw a violin bow over the part *a b*; you will find that all the bits of paper will be thrown off from the part *b d*, excepting the one at *c*; shewing that the point *c* remains at rest, whilst the remainder of the string is vibrating, just as though *c* also had a stop, as at *b*.

136. Sounds in general are conveyed to the ear by means of the air: but water is also a good conductor of sound; as are timber and flannel.

Exp. 1. A bell rung under water returns a tone as distinct as if rung in air.

2. If you stop one ear with a finger, and the other by pressing it close to a long stick or piece of deal board, and a watch be held at the other end of the wood, the ticking will be heard, be the stick or board ever so long.

3. If you tie a poker or any piece of metal on the middle of a strap of flannel, about two or three feet long, and then press with the thumbs or fingers the ends of the flannel in your ears, while you swing the poker against an iron or steel fender, you will hear a sound like that of a very heavy church bell.

4. If two persons stop their ears, they may converse with each other, by holding the two ends of a stick between their teeth, or, only resting the ends of the stick against their teeth. The same may be done by a series of sticks, with the ends touching each other. The same effect is also produced if the end of the stick rest on the throat, or breast, or if one end of it touch a vessel into which the other speaks. In the last instance the sound is most distinct if the vessel is capable of a tremulous motion, as one of glass, bell metal, or copper.

Sound may also be conveyed from one person to another by a string stretched between their teeth.

137. Sound travels at the rate of 1142 feet in a second, or about 13 miles in a minute. This is the case with all kinds of sounds: the softest whisper flies as fast as the loudest thunder.

Obs. The velocity of sound has been applied to the measurement of distances.

1. A ship at sea in distress fires a gun, the light of which is seen on shore 20 seconds before the report is heard, therefore it is known to be at the distance of 20 times 1142 feet, or little more than 4 1-3 miles.

2. I see a vivid flash of lightning, and if in three seconds I hear a tremendous clap of thunder, I instantly know that the

thunder cloud is only two-thirds of a mile distant, I sho
therefore retire instantly from any exposed situation.

3. The pulse of a healthy person beats about 76 times i
minute; if, therefore, between the flash of lightning and
thunder I can feel 1, 2, 3, 4, &c. beats of my pulse, I kn
the cloud is 900, 1800, 2700, 36,000 feet from me.

138. Sound, like light, after it has been reflec
from several places, may be collected into one p
as a focus, where it will be more audible than in
other part; and on this principle WHISPERING G
LERIES are constructed.

Obs. In the reflection of sound as well as of light, the angl
reflection is equal to the angle of incidence. By the same
therefore, sound may be collected into a focus.

Exp. 1. If the pulses of air conveying sound be suffere
impinge on a concave surface, the reflected vibrations
converged into a focus.

2. The same effect is produced whenever a number of p
surfaces are so situated that the reflected sounds meet,
cross each other at a certain point. If the ear be place
this point, the sound will be audible in proportion to the nu
ber of surfaces so placed. The famous whispering galler
St. Paul's is on this principle.

139. SPEAKING TRUMPETS, and those made to as
the hearing of deaf persons, depend on the reflect
of sound from the sides of the trumpet, and also by
being confined and prevented from spreading in ev
direction.

Obs. 1. A speaking trumpet, to have its full effect, mus
directed in a line towards the hearer; the report of a gu
cannon is much louder when fired towards a person, than
placed in a contrary direction.

2. The human voice is produced by the expulsion of
from the lungs, and by the vibrations excited in that air, b
very small membrane called the *glottis*, in its passage thro
the trachea or windpipe; and by the subtle modificatio
the mouth, tongue, and lips.

3. Singing is performed by a very delicate enlargemen
contraction of the glottis, aided likewise by the mouth
tongue for articulation.

4. In stringed instruments the air is struck by the string,
the vibrations of the air produce corresponding sounds in

ear; but in pipes the air is forced against the sides by the breath, and its vibrations or tones produced by the re-action of the sides.

140. An ECHO is the reflection of sound striking against a surface fitted for the purpose, as the side of a house, a brick wall, hill, &c. and returning back again to the ear, at distinct intervals of time.

Obs. 1. If a person stand about 65 or 70 feet from such a surface, and perpendicularly to it, and speak, the sound will strike against the wall and be reflected back, so that he will hear it as it goes to the wall, and again on its return.

2. If a bell situated in the same way be struck, and an observer stand between the bell and the reflecting surface, he will hear the sound going to the wall, and again on its return.

3. If the sound strike the wall obliquely, it will go off obliquely, so that a person who stands in a direct line between the bell and the wall, will not hear the echo.

141. Concord is any succession of sounds that excite in the ear certain agreeable sensations. Sound is therefore the subject matter of musical science. Harmony is the coincidence of two or more sounds, which by their union afford to the mind pleasure and delight.

Obs 1. Concord arises from the agreement of the vibrations of two sonorous bodies; so that some of the vibrations of each strike upon the ear at the same instant.

Thus if the vibrations of two strings are performed in equal times, the same tone is produced by both, and they are said to be in *unison*. If the vibrations strike the ear at different times, there is no unison, and consequently a *discord* is produced.

Obs. 2. Concord is not confined to unison. In this case no variety of tones would be produced. It is the effect of *agreement* between vibrations.

Illus. If the vibrations of one string are double those of another in the same time, the second vibration of the latter will strike upon the ear at the same instant with the first vibration of the former: this makes the concord of an octave.

142. Two strings of equal length, tension and thickness, by performing their vibrations together, will sound the same note, or be in unison. Two pipes of the same length and diameter will agree in the same manner. Large instruments & long strings produce grave or deep

tones: small instruments and short strings produce acute and high tones.

Obs. In the case of the strings, the air is struck by the body, and the sound is excited by the vibrations: in that of the pipes the body is struck by the air, but as action and reaction are equal, the effect is the same.

2. Let a musical string of any length be divided into two equal parts by a bridge in the middle; and the sound of each half is eight notes, or an octave, higher than the tone of the whole string.

Organ pipes produce grave or acute tones in proportion to their length and size. It is the shortest string of a harpsichord which yields the highest notes.

143. Sounds may be conveyed to a much greater distance through a continuous tube, than through the open air.

Illus. Pipes are used in taverns, running from one room to another to convey orders to the servants.

Dr. Herschel employs a similar tube attached to his forty feet telescope for communicating his observations to an assistant who sits in a small house near the instrument; and thus under cover notes them down the particular time at which they were made.

Obs. The tubes used to convey sounds are called acoustic tubes.

It is by means of such tubes that the deception of what is called the *invisible lady* is carried on. In this exhibition a square railing of wood is fixed in the middle of the room, and within the railing a globe is fixed, having four trumpets inserted into it, one opposite to each side of the railing. The spectators ask a question by speaking into one of the trumpets, and then on holding the ear to the same trumpet, they receive the answer. This deception is performed by conveying the sound by tubes which are carried from one room to another under the flooring, and within the bar of the railing to a small aperture opposite to the mouth of the trumpet. When the question is asked it is conveyed by this pipe to a person placed in the next room, and the reply is conveyed back to the trumpet by the same tube.

QUESTIONS ON ACOUSTICS.

Of what does the science of *acoustics* treat?
How does sound arise, and how is it communicated?
How is this proved?

What are the principal causes of the varieties of sounds?
What is said about the *pitch* of a sound?
On what does the continuance of vibrations depend, for a longer or shorter time?
What other substances besides air conduct sound?
Give illustrations of the power of liquids and solids to conduct sounds.
At what rate does sound travel through the air?
What is said about measuring distances by the velocity of sound?
On what principle are *whispering galleries* constructed?
What is said of plain and concave surfaces in converging sound into a focus?
On what principle are *speaking trumpets* constructed?
How is the human voice produced?
What parts are concerned in the modulation of the voice in singing?
How does the production of sound by pipes differ from that by strings?
What is an Echo?
How is this accounted for?
What is said concerniug the reflection of light and sound following the same laws?
What is *concord?*
From what does concord arise?
When will two strings, or two pipes be in unison?
How may sounds be conveyed to a greater distance than through the open air?
What is said of Dr. Herschel; the *invisible lady*, &c.?

OF OPTICS;

OR

THE LAWS OF LIGHT AND VISION.

144. LIGHT consists, either of small particles emanating from a luminous body, or of vibrations excited by combustion in an universal medium, which, proceeding to the eye, produce the perception of *vision.*

Obs. 1. It is evident we cannot see any object by willing or wishing to see it; but that something must pass from the ob-

ject to the eye, because no effect can take place without proximate cause.

2. Sir Isaac Newton supposed rays of light to consist of ex ceedingly small particles, infinitely smaller than sand, movin from luminous bodies; but the moderns suppose them to con sist of the undulations of an elastic medium, which fills a space, and which produces the sensation of light to the ey just as the vibrations of air produce the sensation of sound the ear. We shall not prefer either hypothesis in the pages, because either of them will account equally for all th phenomena of light.

145. A *Ray, or pencil of Light*, is any exceeding small portion of light which comes from a lumino body. A *Beam* of light, is a body of parallel rays; *Pencil* of rays, is a body of diverging or converging ray

146. Any body which is transparent, or which a fords a ready passage for light, is called a transpare *Medium*, as air, glass, water, &c. Bodies which d not allow the passage of light through them, a called *Opaque*, as stone, wood, &c.

147. Rays of light which coming from a point, co tinually separating as they proceed, are called *Diver ing Rays*. Rays which tend to a common point a called *Converging Rays*. When the lines in whi they move are parallel, they are called parallel ray

148. The point from which diverging rays procee is called the *radiant point;* that to which conver ing rays are directed is called the *focus*. A ray light, bent from a straight course in the same mediu is said to be *inflected;* when turned back on the surfa of a body, it is said to be *reflected;* and, when turn out of its course in passing out of one medium in another, it is said to be *refracted*.

149. Every visible body emits particles of light, reflects vibrations from its surface in all directio which, passing without any obstruction, move with the same medium in right lines.

Obs. Wherever a spectator is placed in respect to the lu nous body, every point of that part of the surface which turned towards him is visible to him; the particles of vib

tions of light are, therefore, emitted in all directions, and those rays only are intercepted in their passage by an interposed object, which would be intercepted upon the supposition that the rays move in right lines.

Exp. 1. Let a portion of a beam of light be intercepted by any body; the shadow of that body will be bounded by right lines passing from the luminous body, and meeting the lines which terminate the opaque body.

2. A ray of light, passing through a small orifice into a dark room, proceeds in a straight line.

3. Rays will not pass through a bended tube.

4. Rays of light may, therefore, be properly represented by right lines.

150. Rays or vibrations of light move with great velocity; for the flash of a gun, fired at a considerable distance, is seen some time before the report is heard. The clap of thunder is not heard till some time after the lightning has been seen.

Obs. This proposition is proved by observation made on the satellites of the planet Jupiter, and on the aberration of the rays of light from the fixed stars, from whence it will be seen, that the velocity is at the rate of 200,000 miles in one second of time.

151. The particles of light must be exceedingly small, if they are particles; or the force of the vibrations must be very delicate; otherwise their velocity would render their momentum too great to be endured by the eye without pain.

Exp. 1. If a candle be lighted, and there be no obstacle to obstruct the progress of its rays, it will fill all the space within two miles every way before it has lost the least sensible part of its substance.

2. Rays of light will pass without confusion through a small puncture in a piece of paper, from several candles in a line parallel to the paper, and form distinct images on a sheet of paste-board placed behind the paper.

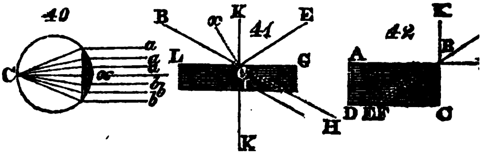
152. The quantities of light, received from a luminous body upon a given surface, are inversely as the squares of the distances of the surface from the *luminous body.*

Obs. The direct light of the sun is calculated to be eq that of 6560 candles placed at the distance of one foot fr object; and that of the moon to the light of one candle a feet distance, of Jupiter at 1620 feet, and of Venus at 42

Exp. The light, passing from a candle or any lu body, will diverge as it proceeds, and will illuminate su which surfaces will be to each other as the squares of th tances from the candle. Thus, if at the distance of o the candle illuminates any surface, at double the dist will illuminate a surface equal to four times, and at the d of three feet it will illuminate a surface equal to nine and, consequently, the surfaces illuminated are as the s of the distances, 1, 2, and 3.

153. If rays proceed from a radiant point at finite distance, their divergency is so trifling, tha may be considered as parallel.

Obs. 1. Hence all the rays which could come from t tre, or any other given point, of the sun's surface, are co ed as parallel at the immense distance of the earth.



2. To understand the nature of the convergency, di cy, and parallelism of rays of light, see fig. 40. A C *diverges* rays of light towards x. They are said to when considered as flowing from x towards C. And *parallel* as flowing from x towards a and b. C is the the *converging* rays; and the imaginary focus of the di rays.

154. When rays of light pass *obliquely* out transparent medium into another, which is eithe dense, or more rare, they are bent out of their course, and they are then said to be REFRACTE

155. Rays of light are always refracted tow perpendicular to the surface in a *denser* mediu this refraction is, more or less, in proportion as th fall, more or less, obliquely on the refracting su

Exp. Let B C, fig. 41, be supposed to be a ray of light passing out of air into water or glass, L G, at the point C; K K is a line drawn perpendicular to L G, and the ray B C, instead of proceeding along C H will in so passing, be bent towards the perpendicular C as long as C I.

156. On the contrary, when light passes out of a denser into a *rarer* medium, it moves in a direction *farther from* the perpendicular.

Exp. 1. Thus if the ray C I, fig. 41, pass out of the glass into air, it will not proceed in C x but in the direction C B, farther from F C than C.

2. Take a pan A B D C, fig. 42, with an upright side, into a dark room; let in, by means of a small hole in a window shutter, a ray of light G B, so as to fall upon the bottom of the pan at E; mark the spot E; then without moving the pan, fill it with water, and the ray now will not pass on to E, but will be refracted down to F. The candle G will answer as well as the direct rays of the sun.

3. If a shilling be stuck on the part F with wax, so that an eye at G cannot see it when the pan is empty, it will become visible the moment the pan is filled with water.

4. Take a glass goblet half full of water and put a shilling into it, then put a saucer or plate upon it, and holding it tight on, turn plate and glass together; a by-stander unacquainted with the laws of refraction, will suppose that he sees a shilling and a half crown; the one is seen by refraction through the water, the other by the rays after refraction at the surface.

157. The *Angle of Incidence*, is that which is contained between the line described by the incident ray, and a line perpendicular to the surface on which the ray strikes, raised from the point of incidence. Thus in fig. 41, the angle B C K is the angle of incidence.

158. The *Angle of Reflection*, is that which is contained between the line described by the reflected ray and a line drawn perpendicularly to the reflecting surface at the point in which the ray passes through that surface. Thus, in fig. 41, E C K is the angle of reflection.

159. Availing themselves of the principle of *refraction*, philosophers have so contrived surfaces, that the perpendiculars to them constantly vary, and produce

new and important effects. This they have do means of convex and concave glass *lenses*, so as t lect or disperse the rays of light which pass thro

160. There are various kinds of lenses nam cording to their *forms*.

43

A *plano-convex lens* h side flat, and the othe vex, as A, fig. 43.

A *plano-concave* is flat on one side, and conc the other, as B, fig. 43.

A *double-convex* is convex on both sides, as C, f

A *double-concave* is concave on both sides, as D;

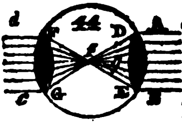
A *meniscus* is convex on one side, and conc the other, as E, fig. 43.

The *axis* of a lens, is a line passing throu centre: thus F G is the axis to all the five lens

161. If parallel rays fall upon a plano-conve they will be so refracted as to unite in a point b called the principal focus, or focus of paralle

Exam. Thus the parallel rays *a b*, fig. 40, falling u *lens* are refracted towards the perpendicular C *x*, and a focus at C.

44



162. The distance from the of the glass to the focus, is cal *focal distance;* which focal d in a plano-convex lens is equa diameter of the sphere of wh lens is a portion, fig. 40, and th distance of a double-convex lens, is equal to th us of a sphere of which the lens is a portion, f

163. All the parallel rays of the sun whic through a convex glass as DE, are collected in cus *f* and the force of the heat at the focus is common heat of the sun, as the area of the gla the area of the focus.

Illus. If a lens four inches in diameter collect the sun's rays into a focus at the distance of twelve inches, the image will not be more than one-tenth of an inch in diameter, the surface of this little circle is 1600 times less than the surface of the lens, and consequently the heat will be 1600 times greater at the focus than at the lens.

Cor. 1. Hence the construction of common burning-glasses, which are all double convex lenses.

2. Hence the reason why furniture has been set on fire by leaving a globular decanter of water incautiously exposed to the rays of the sun, which acts as a double convex lens.

164. If another double convex F G, fig. 44, be placed in the rays at the same distance from the focus, it will so refract the rays back again, that they *will* go out of it parallel to one another.

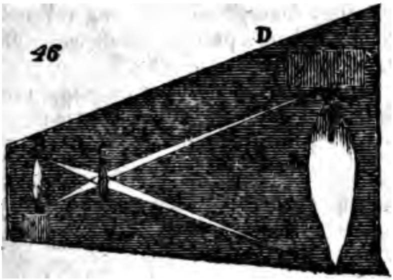
Illus. It is evident that all the rays, except the middle one, cross each other in the focus *f*, of course the ray D A, which is uppermost in going in, is the lowest in going out, as G *c*.

Exp. 1. If a candle be placed at *f*, the diverging rays between F G, will, upon going out of the lens, become parallel at *d c*.

2. If a candle be placed nearer the glass than the focus, the rays will *diverge*, after going through the lens.

3. If the candle be placed farther from the glass than the focus, the rays will *converge*, after passing through the glass, and meet in a point which will be more or less distant from the glass, as the candle is nearer to, or farther from, its focus.

4. When the rays meet, they will form an inverted image of the flame of the candle. Suppose B, a candle, fig. 46, and C a convex lens, then on a dark skreen D, the image A of the candle will be produced, and will be reversed, because the rays cross each other in passing through the lens.



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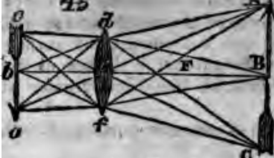


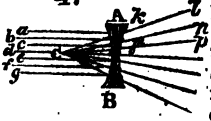
5. If an object A B C, fig. 4[5] be placed beyond the focus F [of] the glass *d e f*, some of the ra[ys] which flow from every point [of] the object on the side next t[he] glass, will fall upon it, and aft[er] passing through it they will [be] converged into as many poi[nts] on the opposite side of the glass, where the image of the wh[ole] will be formed, which will be inverted. Thus the rays flo[w]ing from A, as A *d*, A *e*, A *f*, will converge in the space *d e* and by meeting in *a* will there form the image of the point A and so of those rays flowing from B and C, and of course of the intermediate parts.

6. If the object A B C, be brought nearer the glass, the pi[c]ture *a b c* will be removed to a greater distance from it.

7. The picture will be as much larger or less than the o[b]ject, as its distance from the glass is greater or less than t[he] distance of the object.

165. When parallel rays pass through a doub[le] concave lens, they will diverge after passing throu[gh] the glass, as if they had come from a point in the ce[n]tre of the concavity of the glass.

47



Exam. If the rays *a b c*, &c. fig. 4[7] pass through A B, and C be the cent[re] of concavity, then the ray *a* after pas[s]ing the glass, will go on in the directi[on] *k l*, as if it had come from *c* and no gl[ass] in the way; the ray *b* will go on in th[e] direction *m n*, and so on.

166. When parallel rays pass through a plano-con[]cave lens, they diverge after passing through it, as [if] they had come from a point at the distance of a whol[e] diameter of the glassy concavity.

167. The following are the principal phenome[na] of rays in connexion with various lenses;

Obs. 1. Through a *convex surface*, passing out of a rarer int[o] a denser medium, *parallel rays* will become converging.

Diverging rays will be made to diverge less, to become pa[]rallel, or to converge, according to the degree of divergency be[]fore refraction, or of the convexity of the surface.

Converging rays towards the centre of convexity, will suffer no refraction.

Converging rays to a point beyond the centre of convexity, will be made more converging.

Converging rays towards a point nearer the surface than the centre of convexity, will be made less converging by refraction.

But when the rays proceed out of a denser into a rarer medium, the reverse occurs in each case.

2. When rays proceed out of a rarer into a denser medium, through a CONCAVE SURFACE if *parallel* before refraction, they are made to diverge.

If they are *divergent*, they are made to diverge more, to suffer no refraction, or to diverge less, according as they proceed from some point beyond the centre, from the centre, or from some point between the centre and the surface.

If they are *convergent*, they are either made less converging, parallel, or diverging, according to their degree of convergency before refraction:

And *the reverse*, in passing out of a denser into a rarer medium.

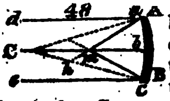
Exp. Most of the preceding propositions may be confirmed, in a room from which all external light is excluded, by placing a convex lens, or concave, fixed in a frame which moves perpendicularly upon an oblong bar of wood, or table, at different distances from a lighted candle placed perpendicularly on the same bar of wood, and receiving the images upon white paper. Upon this bar of wood, on one side of a line over which the convex lens is placed, let a line perpendicular to the last mentioned line be divided into parts, 1, 2, 3, 4, &c. each equal to the distance of the focus of parallel rays; and on the other side of the lens, let a line be divided in the same manner, and let the first division, which is farther from the lens than the focus, be subdivided into parts respectively, equal to 1-2, 1-3, 1-4, &c. of the distance of the focus of parallel rays: if a candle be placed over the division 2, it will form a distinct image on a paper held over the division 1-2: if a candle be over 3, the image will be at 1-3, &c. whence it appears, that the distances of the correspondent foci vary reciprocally; or by holding a large double convex lens, or burning glass, in the sun's rays, and receiving the image on white paper, or other substance at different distances.

168. When rays of light strike against a smooth surface, and are sent back from it, they are said to be RE-

FLECTED, and the ray that comes from any body, and falls upon the reflecting surface, the *incident ray*.

Exam. If L G, fig. 41, be a reflecting surface, glass, then B C is the incident ray, and C E is the r

159. The *angle of incidence* is that whi tained between the incident ray, and a per to the reflecting surface in the point of ref B C K, fig. 41. The *angle of reflection* is tained between the perpendicular and the ray, as K C E, fig. 41. And the angle of and reflection are always equal.



Obs. 1. Let the lines C *a* and be drawn, which are perpendic concave surface *a e*, and it w that the angle of incidence *d a* to the angle of reflection C *a m* is equal to C *e m*.

2. Sir Isaac Newton explains the cause of r supposing, that light, in its passage from the lumin disposed to be alternately reflected by, and transmit any refracting surface it may meet with; that t tions, which he calls fits of easy reflection and ea sion, return successively at equal intervals; and t communicated to it, at its first emission out of th body it proceeds from, probably by some very sub tic substance diffused through the universe, in th manner: As bodies falling into water, or passing air, cause undulations in each, so the rays of light vibrations in this elastic substance. The quickn vibrations depending on the elasticity of the medi quickness of the vibrations in the air, which props depend solely on the elasticity of the air, and n quickness of those in the sounding body,) the m particles of it may be quicker than that of the therefore, when a ray, at the instant it impinge surface, is in that part of a vibration which is co motion, it may be reflected. He farther suppose light falls upon the first surface of a body, none there, but all that happens to it there is, that ever not in a fit of easy transmission, is there put into when they come at the other side, (for this elasti easily pervading the pores of bodies is capable of t

brations within the body as without it) the rays of one kind shall be in a fit of easy transmission, and those of another in a fit of easy reflection, according to the thickness of the body, the intervals of the fits being different in rays of a different kind.

3. This doctrine of fits does not accord with the general simplicity of nature, or of the other parts of this great man's philosophy. It seems far more reasonable to consider the phenomena of light, as being produced by vibrations of an universal medium, the intervals between the vibrations corresponding with the fits above supposed. Such ideas of vibrations correspond too, with the general analogies of nature in other particulars.

170. The following are the chief phenomena of reflected rays:

1. *Parallel* rays reflected from a CONCAVE surface, are made converging.

Converging rays falling upon a *concave* surface, are made to converge more.

Diverging rays falling upon a *concave* surface, if they diverge from a focus of parallel rays, become parallel.

If from a point nearer to the surface than that focus, they diverge less than before reflection.

If from a point between that focus and the centre, they converge after reflection to some point, on the contrary side of the centre, and farther from the centre than the point from which it diverged.

If from a point beyond the centre, the reflected rays will converge to a point on the contrary side, but nearer to it than the point from which they diverged.

If from the centre, they will be reflected thither again.

Exp. Place a concave mirror at proper distances from an open orifice, or a convex, or a concave lens, through which a beam of solar rays passes, and verify the preceding propositions.

2. *Parallel* rays reflected from a CONVEX SURFACE, are made diverging.

Diverging rays reflected from a *convex* surface are made more diverging.

Converging rays reflected from a *convex* surface, if they tend towards the focus of parallel rays, will become parallel.

If to a point nearer the surface than that focus, will converge less than before reflection.

If to a point between that focus and the centre, will diverge as from a point on the contrary side of the centre farther from it than the point towards which they converged.

If to a point beyond the centre, they will diverge as from a

the retina, unless the object be brought near to it; in wh case the image is cast farther back. In others, the humours the eye have so little convexity, that the focal point lies be the *retina;* whence, unless the object is removed to a gre distance from the eye, the vision will be indistinct.

175. When the diameter of an object is given, apparent diameter to the eye, is inversely as its tance from the eye, and the apparent diameter is angle which it subtends to the eye; so that its ap rent size is as the angle which it subtends to the e

Obs. 1. The angle subtended as the least visible object, ed by the writers on optics, the *minimum visible*, cannot be a rately ascertained, as it depends upon the colour of the ob and the ground upon which it is seen; it depends also the eye. Mr. Harris thinks the least angle for any objec be about 40 seconds; and at a medium, not less than two nutes. To the generality of eyes, the nearest distance of tinct vision, is about 7 or eight inches. Taking 8 inches that distance, and 2 minutes for the least visible angle, a bular object of less than the three-hundredth part of an i cannot be seen.

2. The apparent diameter of an object is as the diamete its image upon the retina; and the diameter of the ima when the object is given, is *inversely* as the distance of the ject; therefore the apparent diameter of the object is also *versely* as the distance of the object. The same may be pro of any apparent length whatsoever.

3. Hence the apparent diameter of an object may be m nified in any proportion; for the *less* the distance of the from the object, the greater will be its apparent diameter. without the help of glasses, an object brought nearer the than about five inches, though it appears larger, will at same time appear confusedly.

4. Many deceptions in vision arise from the above conside tion. We judge of the *distance* of any object by the visi length of the plane, which lies between the eye and the obje When this method fails us, we compare the known magnitu of the object with its present apparent magnitude; or compare the degrees of distinctness with which we see several parts of an object; or we observe whether the chan of the apparent place of an object when viewed from differ stations, or its *parallax*, be great or small, this change be always in proportion to the distance of the object. On t *principle*, we may judge of the distance of a near object,

observing the change which is made in its apparent situation, upon viewing it successively with each eye singly. Or, since it is the difference of the apparent place of an object, as viewed by each eye separately which makes an object to be seen double unless we turn both eyes directly towards it, and since in doing this, where the distance is very small, we turn the eyes very much towards each other, and less at a greater distance; the different sensations accompanying the different degrees in which the eyes are turned towards each other, afford by habit, a rule for judging of the distance.

5. In objects placed at such distances as we are used to, and can readily allow for, we know, by experience, how much an increase of distance will diminish their apparent *magnitude*, and, therefore, instantly conceive their real magnitude, and neglecting the apparent, suppose them of the size they would appear if they were less remote; but this can only be done, where we are well acquainted with the real magnitude of the object; in all other cases, we judge of magnitudes by the angle which the object subtends at the known, or supposed, distance; that is, we infer the real magnitude from the apparent magnitude in comparison with the distance of the object.

OF COLOURS.

176. Rays of light are *differently refrangible*, or *refractible*, that is to say, some are more easily turned out of their course than others;—and are *differently reflexible*, when some are more easily reflected than others.

Obs. The powers of rays in regard to their refrangibility or reflexibility, are ascribed, on the hypothesis of their being particles like sand, to the different *momenta* of the particles; and on the hypothesis of their being simple vibrations like undulations of water, to the vivacity or acuteness of the vibrations. It seems, indeed, evident, that the rays which are turned the most out of their course by a refrangible medium have *less* powers or momenta, than those which are the least diverted from their course. Different colours are therefore simply the effect of the different perceptions produced on the optic nerves by the different forces or the action of the rays, the red being the most forcible, and the violet the least.

177. Light is called *homogeneous*, when all the rays are equally refrangible; and *heterogeneous*, when some

rays are more refrangible than others. The *colours* produced by homogeneous rays, are called *primary* or *simple* colours; those of heterogeneous, *secondary* or *mixed*.

178. To examine the different colours of a ray of light, a small hole must be made in the shutter of a dark room, and the ray must fall upon a prism in an oblique direction.

Obs. Prisms are commonly made of solid glass, but students who do not possess one of this kind, may easily make a substitute. Take three pieces of plate glass, (the kind of which looking glasses are made) each four, or six inches long and two or three inches wide; get made of tin a frame consisting of the two ends in the exact shape of the three pieces of glass placed in the form of a triangle, with a strip of tin running from each angle of one end to the angles or corners of the other. These strips are bent so as to receive the two edges of the glass plates. When the frame is complete, except the soldering in of one of the ends, fix the glass plates in their places, and then have the end soldered. The tin forming the ends is turned up so as to receive the plates, and one of the ends is furnished with a spout to pour in water. When this is done, the vessel is made water tight, by stopping with putty all the crevices between the glass and tin. The prism is then filled with clear water by the spout and corked up.

Illus. 1. Let A B, figure 50, represent part of the shutter of the window of a room, in which no light enters except through the hole C. If the light of the sun be received upon a screen at any distance from the hole, as at E, a circular luminous spot will be formed upon the screen, which is larger in diameter than the hole at C. Place a glass prism E before the hole, so that the light may pass through in a direction perpendicular to the axis of the prism; and instead of going straight from E to F, the light which comes through the hole, will, by passing through the prism, be bent and dispersed in such a manner, as to form a coloured spectrum or

image G H upon a screen which may be situated at any distance from the prism, but below the straight direction C F. The length of the spectrum G H is equal to about five times its breadth, and is terminated by semicircular ends. The highest part G is of a beautiful *red* colour, which, by insensible shades, degenerates into an *orange*, then a *yellow*, a *green*, a *blue*, an *indigo*, and a *violet*, which is the colour next to H, viz. at the lowest part of the spectrum.

2. Or in fig. 51, let E G be a shutter, F a hole, S S a ray or direction of solar light, A B C a glass prism, then the light falling on B C will be unequally refracted to the wall M N, and produce the coloured spectrum P T. The violet being the most, and the red the least turned out of their course.

179. If the whole spectrum be divided into 360 parts, the *red* will occupy 45 of them, the *orange* 27, the *yellow* 48, the *green* and the *blue* 60 each, the *indigo* 40, and the *violet* 80. By mixing the seven primitive colours in these proportions, a dusky white is obtained. And the seven colours are reducible to three, viz. the red, blue, and yellow.

Exp. Paint on a circular board the seven colours in their proper proportions, and then whirl the board with great velocity, it will appear of a dirty white. If the colours were more perfect and accurately defined, the white would appear more perfect also.

180. The colours of homogeneous light can neither be changed by refraction nor reflection, and the whiteness of the sun's light arises from a due mixture of all the primary colours.

Exp. 1. Let a beam of homogeneous light pass through a round hole in a pasteboard, and then be refracted by a prism on the other side, the colour of the rays will remain the same.

2. Red lead, viewed in homogeneous red light, will be red, but if placed in green, or any other homogeneous light, it will take the colour of the rays which fall upon it.

181. The colours of all bodies are either the simple colours of a homogeneous light, or such compound colours as arise from the mixture of homogeneous light.

Obs. 1. Each sort of light having a peculiar colour of its own, which no refraction or reflection can alter, since bodies appear coloured only by reflected light, their colours can be no other than the colour of some single homogeneous light, or of a mixture of different sorts of light.

2. When the thickness of the particles of a body is such that one sort of colour is reflected, other colours will be transmitted, and therefore the body will appear of the first colour And, in general, a less thickness is found to be necessary to reflect the most refrangible rays, as violet and indigo, than those which are least refrangible, as red and orange. Sir I. Newton, from a variety of experiments on light and colours, concludes that every substance in nature is transparent, provided it may be sufficiently thin.

3. Mr. Delval has, however, by a great variety of wel conducted experiments, shewn that colours are exhibited not by reflected, but by transmitted light. This he proves by covering coloured glass, and other transparent coloured media, on the further surface, with some substance perfectly opaque, when he found that they reflected no colour, but ap peared perfectly black. He concludes, therefore, that, a the fibres of mineral and animal substances are found, whe cleared of heterogeneous matters, to be perfectly white, th rays of light are reflected from these white particles, throug the coloured media with which they are covered; that thes media serve to intercept and impede certain rays in thei passage through them, while a free passage being left t others, they exhibit, according to these circumstances, diffe rent colours.

4. Mr. Delval concludes, (1,) That the colouring particle do not reflect any light. (2,) That a medium, such as Sir I Newton described, is diffused over the anterior and furthe surfaces of the plates, whereby objects are reflected equall and regularly as in a mirror.

5. To determine the principle on which opaque bodies ap pear coloured, it must be recollected, first, that all the colour ed liquors, appear such only by transmitted light; and, se condly, that these liquors, spread thinly upon a white ground exhibited their respective colours; he therefore conclude that all coloured bodies, which are not transparent, consist of substratum of some white substance, which is thinly covere with the colouring particles.

6. On extracting, by means of spirits of wine, the colour ing matter from the leaves, wood, and other parts of veget bles, he found that the basis was a substance perfectly whit He also extracted the colouring matter from different anim substances, as flesh, feathers, &c. when the same conclusi was obtained. Flesh consists of fibrous vessels, containi blood, and is perfectly white when divested of blood by abl tion, and the red colour proceeds from the light which is r

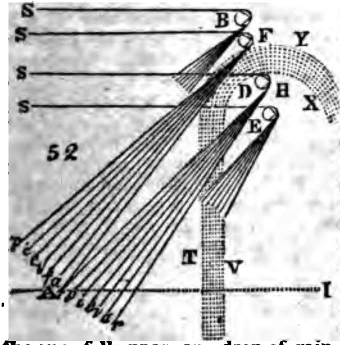
flected from the white fibrous substance through the red transparent covering formed by the blood. The result was the same from an examination of the mineral kingdom.

OF THE RAINBOW.

182. *The Rainbow* is a meteor in form of a party-coloured arch, or semicircle, exhibited only at the time when it rains. It is always seen in that point of the heavens which is opposite to the sun, and is occasioned by the refraction and reflection of his rays in the drops of falling rain. There is likewise, though not always distinctly visible, a secondary, or much fainter rainbow, investing the former at some distance.

Obs. When the sun shines upon drops of rain as they are falling, the rays which come from those drops to the eye of the spectator, after one reflection and two refractions, produce the innermost, or PRIMARY RAINBOW.

Fig. 52, representing the *refraction* and *reflection of light falling on drops of water, in the innermost or primary rainbow.*



Let TFY be the innermost or primary rainbow, the outer part of which TFY is red, and the inner part VDX violet, and the intermediate parts reckoning from the red to the violet, orange, yellow, green, blue, indigo. Suppose the spectator's eye at A, and let AI be an imaginary line from the centre of the sun to the eye of the spectator. If a beam of light S coming from the sun, falls upon any drop of rain F, and the rays which emerge at F, make an angle FAI of 42 degrees 2 minutes with the line AI, these rays make the same angle with the

incident rays, and consequently are red.* Hence th
F will appear red; for all the other rays which emerg
F, and would be effectual if they fell upon the eye, be
fracted more than the red rays, will pass above the e
another beam of light S falls upon the drop D, and the
tual rays emerging at H, make an angle of 40° 17′ wi
incident rays, the drop D will be of a violet colour, for
other rays which emerge from H, and would be effec
they came to the eye, being refracted less than the
rays, will pass below the eye. The intermediate dro
tween F and D will, for the same reasons, be of the in
diate colours. And that which has been proved conc
the drops in the line F D, may be shewn in any other
drops in which the angles made by the emerging and i
rays are equal. Thus, wherever a drop of rain is pla
the angle which the effectual rays make with A I is eq
the angle F A I, or is 42° 2′, any such drop will appe
If F A I were turned round upon the line A I, so th
end of this line should always be at the eye, and the o
I opposite to the sun, in this revolution the drop F wou
scribe a circle, of which I would be the centre, and b
an arc. And since in this revolution the angle F A
tinues the same, if the sun was to shine upon this dro
revolves, the effectual rays would make the same angl
the incident rays, in whatever part of the arc T F Y th
may happen to be; and, consequently, in whatever
the arc the drop F is, it will appear red. Now as inn
ble drops are falling at once in right lines from the
whilst one drop is at F, there will be others at T Y, and
other part of the arc, which will appear red in the sam
ner that F would have done in the supposed circular r
tion. Therefore, when the sun shines upon the rain
will be a red arc T F Y produced opposite to the su
like manner a violet arc V D X will be produced, and
intermediate colours, which will together make up th
mary rainbow. At the eye at A the rays are divided
R red to P purple, just as they present themselves to th
in nature.

Exp. Let a glass globe, filled with water, be exposed
rays of the sun: let the eye of the spectator be so situate
the least refracted ray from the drop, coming to the eye
make an angle of about 42° with the line passing throu

* The angle which the effectual red rays make with th
dent rays, is found to be 42° 20′, that of the violet rays 4

eye and the sun, the red rays only will be seen; if the place of the eye be changed, so as to enlarge this angle, the red will disappear; but if the angle be lessened, the colours of the more refrangible rays will appear.

Obs. 1. Cascades and fountains, whose waters, in their fall, are divided into drops, will exhibit rainbows to a spectator, properly situated, during the time of the sun's shining. This appearance is also seen by moon-light, though seldom sufficiently vivid to render the colours distinguishable. Coloured bows have been seen on grass formed by the refraction of the sun's rays in the morning dew.

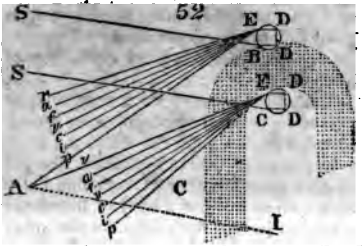
2. Artificial rainbows may be produced by a candle light on the drops of water ejected by a small fountain, or jet d'eau, or from the stream emitted from an eolipile. But the most natural and pleasing is by means of the air fountain, the jet of which is perforated with a great number of very fine holes from which the water spouts so as to form a kind of fluted column. The rainbow is formed by the sun's rays, for the spectator has to place the spouting streams directly in the sun's beams, with his own back to the sun, and being in a direct line with the sun and the centre of the jet, by stooping his head to a certain degree, he will discover the beautiful appearance of the natural prismatic colours, and a small rainbow, on the same principle as those which are seen in the time of rain and sunshine.

183. The primary rainbow can never be a greater arc than a semicircle.

Since the line *a i* fig. 52, is drawn from the sun through the eye of the spectator, and through *i* the centre of the rainbow, this centre is always opposite to the sun. And since the angle *f a i* is an angle of 42° 2′, *f*, the highest part of the bow is 42° 2′ from *i* its centre. If, therefore, the sun is more than 42° 2′ above the horizon, *i*, which is opposite to it, must be more than 42° 2′ below the horizon, and no primary rainbow will be seen. As much as the altitude of the sun is less than 42° 2′, so much will the highest point *f* of the rainbow be above the horizon; and when the sun is in the horizon, *i*, the centre of the bow will also be in the horizon on the opposite side, and half the circle will be visible; but when the sun is set no bow can be seen.

184. When the light falls upon the under parts of drops of rain, some of it, after two reflections and two refractions, comes to the eye of the spectator who had his back towards the sun, and his face towards the drop. And

those rays which are parallel to one another they have been once refracted, and once refle a drop of rain, will be coloured, and produce an rior rainbow, when they emerge after two tions and two reflections.



When the su upon a drop o fig. 52, in th edge of the sec rainbow CBD fectual violet makes an an of 54° 7' wit line drawn fr sun through of the spectat therefore ma same angle with the incident ray S B. Therefore if th tator's eye is at A, all the rays except the violet, will less angle with A I than E A, and fall above the spe eye. In like manner it may be shewn, that from the only red rays will come to the spectator's eye, the re ing below it; and that the rays emerging from the in diate drops between E and F, and coming to A, will at intermediate angles, and present to the eye the in diate colours. If EAI be conceived to turn round u line A I, in such a revolution of the drop E, the angle would remain the same, and consequently the emergi would make the same angle with the incident rays. such a revolution the drop E would describe a circle, of I would be the centre, and C B D an arc. Conseq since the emerging rays make the same angle with th dent ones when the drop is at any other part of the ar E, the colour of the drop will be violet to an eye place in whatever part of the arc the drop is placed. Now there are innumerable drops of rain falling at once, one drop is at E, there will be others in all parts of t which will all appear violet-coloured, for the same reas E would have appeared of this colour in any other part arc. In like manner as the drop F, appears red at F, any part of the arc FD, so will any other falling drop v comes to any part of that arc. The intermediate a formed in the same manner with the violet arc CBD, a

red arc FD: and thus the whole secondary rainbow is produced.

185. The colours of the secondary rainbow are fainter than those of the primary, and are ranged in the contrary order.

Obs. 1. The angle which the violet rays make with the incident ones is found to be 54° 7′, and that of the red rays 53° 57′. At every reflection many rays pass out of the drop without being reflected; consequently, the secondary rainbow which is produced after two reflections, is formed by fewer rays than the first, which is produced after one reflection.

2. Again, in the primary bow, the violet rays, when they emerge effectually, make a less angle with the incident rays, and, therefore, with the line AI, than the red rays. But the rays are here only once reflected, and the angle which the effectual rays make with A I is the distance of the coloured drop from I, the centre of the bow. Therefore, the violet arc in the primary bow will be nearer to the centre of the bow than the red arc, that is, the innermost colour will be violet, and the outermost red. But in the secondary rainbow, the rays are twice reflected; and the violet rays, which emerge so as to be effectual after two reflections, make a greater angle with the incident rays, that is, with the line A I, than the red ones: which angle is the distance of the violet arc from I the centre of the bow. Therefore, the violet arc in the secondary bow will be farther from the centre of the bow than the red arc; that is, the outermost colour is violet, and the innermost red.

OF OPTICAL INSTRUMENTS.

186. A *mirror* or *speculum* is an opaque body, whose surface is finely polished, so that it will reflect the rays of light which fall upon it, and thus represent the images of objects.

Obs. They are made of metal, or glass polished on one side and silvered on the other. There are three kinds of mirrors, viz. the *plane*, the *convex*, and the *concave*.

187. *Concave* glasses are necessary to those whose eyes are too convex.

Exp. If the parallel rays, fig. 48, *d a*, C *m b*, and *e c*, fall upon the concave mirror A B, then *d a* will be reflected along *a m*, C *b* will be reflected along *b m*, and *e c* along *c m*; of course they all meet in *m*: and *m b* is found to be equal to *m* C, or half C *b*.

Illus. When the eye is too round, the rays proceeding from objects are converged to a focus before they get to the retina; to remedy this, a concave glass is used, because the property of this is, to *disperse* the rays which prevent them from coming to a focus so soon as they otherwise would.

188. *Convex* glasses are necessary to those whose eyes are too *flat*.

Illus. When the eye is too flat, the rays proceeding from objects do not converge to a focus so soon as they reach the retina; a convex glass has the property of converging the rays, and of course bringing them to a focus sooner than they otherwise would.

Obs. Were there no other use of the science of dioptrics than that of spectacles, the advantage that mankind receive thereby is inferior to no other benefit, not absolutely requisite to the support of life. For as the sight is the most noble and extensive of all our senses; as we make the most frequent use of our eyes in all the actions and concerns of life: surely that instrument which relieves the eyes when decayed, and supplies their defects, must be estimated as the greatest of all advantages. Forlorn, indeed, must have been the situation of many young, and almost all old people, before this admirable invention.

189. Microscopes are instruments for viewing small objects; and they apparently magnify objects, because they enable us to see them nearer than with the naked eye, without affecting the distinctness of vision.

Exp. Take a piece of brown paper and make a pin-hole in it, then bring the eye close to the hole, and the paper within two or three inches of any small print or object, and it will be apparently much magnified, though without the paper the letters would at that distance be wholly illegible.

Obs. All that the hole or microscope effects is to enable us to see an object *distinctly* much nearer to the eye than it could be seen by the eye unaided. The *magnifying* power is as the proportion of the distance, at which we usually view objects, to that at which the microscope enables us to see them or their true images.

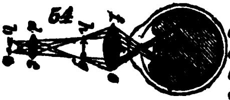
190. There are three kinds of microscopes, the *single*, the *compound*, and the *solar*.

The *single* microscope, is a small double convex lens, *having the object* placed in the focus, and the eye at the *same distance* on the other side. Its magnifying power

is found by dividing seven inches, the least distance at which an object can be seen distinctly by the naked eye, by the focal distance of the lens.

Exp. If the focal distance of the lens be only the 1-4 of an inch, then the diameter of an object will be magnified 28 times (because 7 divided by 1-4 is the same as multiplying 7 by 4,) and the surface will be magnified 784 times.

The *compound* microscope consists of an object-glass and an eye-glass. Its power is in proportion as the image is larger than the object, and also according as we are able to view it at a less distance. There are generally two eye-glasses, by which means the object is less magnified, but more of it is seen.


54

Illus. 1. The object to be viewed is *a b*, fig. 54, *c d* is the object glass, and *e f* the eye glass. The small object *a b*, is placed a little beyond the focus of *d c*, the rays will converge and the image be formed at *g h*. The image, therefore, and not the object, is viewed by the eye, B A E, through the lens *e f*, which is so placed that the image *g h* may be in its focus, and the eye about the same distance on the other side; the rays on each pencil will be parallel after going out of the eye-glass at *e f*, till they come to the eye at *k*, where they will begin to converge by the refractive humour of the eye, and having crossed each other and passed through the chrystalline and vitreous humours, they will form the inverted image A B on the retina.

5. If the image *g h* is 4 times larger than the object *a b*, and by the help of the eye-glass we can view it 7 times nearer than we could by the naked eye, on both these accounts the diameter of the object will be magnified 4 times 7, or 28 times; and the surface 28 times 28, or 784 times.

The *solar* microscope depends on the sun-shine, and is used in a darkened room. It is composed of a tube, a looking-glass, a convex lens, and a single microscope. The sun's rays are reflected by the *looking-glass* through the tube upon the object, the image of which is thrown upon a white screen, sheet, &c. placed at a distance to receive it.

9 *

Obs. The magnifying power of the instrument is in proportion as the distance of the image from the object-glass is greater than the object itself is from it. If the distance of the object from the object-glass be 1-4 of an inch, and the distance of the picture be ten feet, or 120 inches, then the object is magnified in length 480 times, or in surface 230,000.

191. TELESCOPES are used for viewing objects at a great distance; of these, there are two kinds, the *refracting* and *reflecting*.

192. It is the sole business of all Telescopes to enable the eye to see the object under an enlarged angle. For this purpose, a new image of an object is produced by the object-glass of the telescope, and then this image is viewed by means of the eye-glasses.

Obs. As the object or its image is seen by the eye under an enlarged angle, or in the same way in which it would be seen if much nearer to the eye, so the first impression conveyed to the mind by a telescope, is that of bringing the object nearer, which is only another mode of declaring that it is enlarged, or seen under a large angle.

193. The apparent diameter of an object seen through a telescope, is to the apparent diameter of the same object seen by the naked eye, as the distance of the image from the object-glass is to its distance from the eye-glass.

Illus. If the image, formed by the object-glass, were received upon paper, the apparent diameter of the object seen by the naked eye at the station of the object-glass, would be equal to the apparent diameter of the image seen from the same station, and the apparent diameter of the image will of necessity be inversely as the distance of the eye from it, or as the focal distance of the object-glass. If the eye then be placed at the station of the eye-glass, consequently, the image will appear to the eye in that nearer station bigger than at the object-glass in the inverse ratio of the distances. Therefore the apparent diameter of the object seen with the telescope, is to the diameter of the same object seen by the naked eye at the station of the object-glass, as the distance of the distinct image from the object-glass is to the distance from the eye-glass, that is, as the focal distance of the object-glass is to the focal distance of the eye-glass; consequently, if the former be divided by the latter, the quotient will express the magnifying power; thus, if the telescope will magnify ten times in diameter, the *focal distance* of the object-glass is *ten inches*, and that of the *eye-glass one* inch.

Obs. 1. Consequently, a telescope will not magnify an object, unless the focal distance of the object-glass is greater than the focal distance of the eye-glass. And of course the object-glass of a telescope should be less convex than the eye-glass.

2. An object will be equally magnified by two telescopes of very different lengths, if the ratio of the focal distances of the object-glass and the eye-glass be the same in each.

3. And if a telescope is inverted, objects seen through it will be diminished; for the object-glass which has the greater focal distance then becomes the eye-glass, and it reverses the proportion.

4. The visible area, or space which may be seen at one view through a telescope, is as the area of the eye-glass.

5. The brightness of an object seen through a telescope depends upon the area of the object-glass, but not the visible area.

6. The distance of the eye from the eye-glass should be equal to the principal focal distance of the eye-glass.

194. A Telescope, to shew objects in their natural posture, has three eye-glasses. The two additional lenses simply give an erect position to objects. The three eye-glasses have all their focal distances equal, and the magnifying power is found as before, by dividing the focal distance of the object-glass by the focal distance of one of the eye-glasses.

195. *Galileo's telescope* consists of a convex object-glass and a concave eye-glass, so placed that the distance between them is the difference of their focal distances.

Obs. From a distant object, rays fall upon the convex object lens, from which they will proceed towards the focus of that lens. But the concave eye-glass renders the converging rays parallel when they reach the eye; whence an image will be formed upon the *retina*. And the pencils of rays being made more diverging by passing through the concave lens, the visible image is seen under a larger angle than the object, and appears magnified. Also, because the pencils which form the image only cross one another once, the image appears erect.

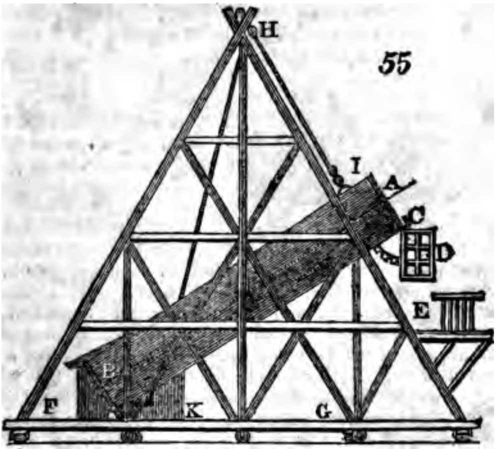
196. *Newton's telescope* consists of a tube, towards the end of which a concave mirror is placed. The converging rays, before they reach the focus, are made to fall upon a plane mirror placed at an angle of 45 deg. and thrown upwards to the focus of a convex lens fixed

in the upper side of the telescope, through which the eye looks down on the object.

197. *Gregory's telescope* consists of a tube on which a concave mirror, having a hole in its centre is placed. Any parallel rays from an object falling upon this mirror, will, after reflection, form an inverted image at its focus. This image, however, is intercepted by a smaller mirror, which reflects it back to an eye-glass in the hole of the large mirror, through which the observer views the object.

Obs. 1. In the telescopes made by Dr. HERSCHEL, the object is reflected by a mirror, as in the Georgian telescope, and the rays are intercepted by a lens at a proper distance, so that the observer has his back to the object, and looks through the lens at the mirror. The magnifying power will be the same as in the Newtonian telescope, but there being no second reflector, the brightness of the object viewed in the Herschel telescope is greater than that in the Newtonian telescope.

2. The tube of Dr. Herschel's grand telescope, is 39 feet 4 inches in length, 4 feet 10 inches in diameter, every part of which is made of iron. The concave surface of the great mirror is 48 inches of polished surface in diameter, its thickness 3 1-2 inches, and its weight is upwards of 2000 lbs. This noble instrument was, in all its parts, constructed under the sole direction of Dr. Herschel: it was begun in the year 1785, and completed Aug. 28, 1789, on which day was discovered the sixth satellite of Saturn. It magnifies 6000 times.



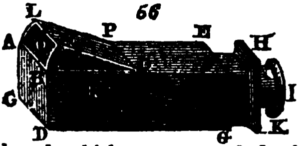
3. ABC is a ray of light, reflected by the great Speculum B, to the eye-glass C. D is a chair for the observer. E a moveable gallery for spectators. FG a smooth base for the frame to turn on. H and I pulleys to move the instrument. K are rooms for assistants.

4. Dr. Priestley observes, that the easiest method of finding the magnifying power of any telescope, by experiment, is to measure the diameter of the aperture of the object-glass, and that of the little image of it, which is formed at the place of the eye. Another method, is to observe at what distance you can read any book with the naked eye; and then removing the book to the farthest distance at which you can distinctly read it by the help of the telescope, the greater distance divided by the less, gives the power of the telescope.

5. Dolland's achromatic telescope by a disposition and mixture of crown and flint object-glasses, destroys the colours which arise in any single object-glass.

198. The *Camera Obscura* is made by fixing a convex glass in a hole of a window shutter, and, if no light enters the room but through the glass, the pictures of all objects on the outside may be seen in an inverted position on a white paper placed in the focus of the lens. If the

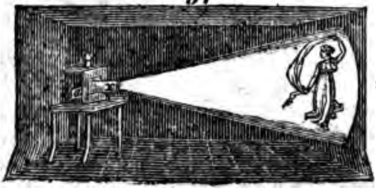
convex lens be placed in a tube in the inside of a bc within which is a looking-glass sloping backwards is called a *portable camera obscura.*



Illus. Fig. 56, represe box consisting of two pa The outer ABCDEFG a shutter or cover LN which moves round a hi PQ, and when open, as in figure, it carries two lat boards which serve to exclude the external light as mucl possible from the rough glass O, upon which the observ to look. The foreside of the box is wanting, and in aperture another narrower box EHIKG slides: this wants the inner side, and has a convex glass lens fixed a If this machine be turned with the lens I towards any obj that are well illuminated, an inverted picture of them wil formed within the box on the side ABCD, and that pict may be rendered distinct by moving the sliding box EH in or out, in order to adjust the focus according to the tance of the objects. At the back part of the box a flat p of looking glass is situated at an inclination of half a right gle, as it is shewn by the dotted lines B R; in consequenc which the rays of light fall upon the looking glass, and reflected upwards to the rough glass O. The picture the formed upon that rough glass, and will appear erect to a sp tator situated behind the box, and looking down upon glass O, from which a drawing may be made.

199. The *Magic Lantern* is an instrument used magnifying paintings on glass, and throwing their ages upon a white screen in a darkened chamber. (S figs. 57 and 58.) And the magic lantern becomes *Phantasmagoria* when the glass slides are rende opaque between the objects.

57



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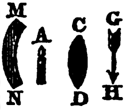
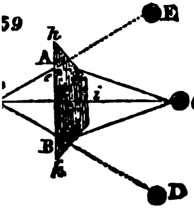


ıs. Fig. 57 represents the machine with the effect it ıces. Fig. 58 shews the internal parts of the machine d at their proportionate distances. The lantern con- a candle A, a reflector M N, which is so situated as to the light, A in its focus. On the fore part of the lantern, is a thick double convex lens C D, or a plane-convex lly called a bull's eye,) of short focus. The lantern is l on every side, so that no light can come out of it, ex- what passes through the lens C D. In the direction of ms, there is a tube x fig. 57, fixed in the lantern, which lateral aperture from side to side; through this the slider *aa* with the painted small images, is moved in an ted position. GH, fig. 58, represents one of these ima- The fore part of the tube x contains another sliding which carries the double convex lens EF. The effect se parts is as follows:—The thick lens CD throws a deal of light from the candle A upon the image GH, increase that light still more, the reflector MN is of- ut not always, placed in such lanterns; for, as the is in the focus of the reflector, the light proceeds in lel lines from the reflector to the lens CD. The image eing thus well illuminated sends forth rays from every , which, by passing through the lens EF are converged focus upon the wall, and form the large images as is in fig. 57. In some magic lanterns, instead of the sin- ns EF, two lenses are used of less curvature, and set at e distance from each other, and act rather better than a lens.

'0. The Multiplying Glass, is made by grind- own the side of a convex glass into several flat ces.

59



Illus. Fig. 59, is the representa- tion of a multiplying glass with the flat sides *h b*, *b d*, *d k*. The ob- ject C, seen by the eye at H, will appear multiplied into as many different objects as the glass con- tains plane surfaces. For since rays flow from the object C to all parts of the glass, and each plane surface will refract these rays to the eye, the same object will appear eye in the direction of the rays which enter it through *urface*. Thus the rays falling in the direction C i H will *he object in its* true place at C, because there they suffer

no refraction; but the rays falling upon the surfaces, *h b* and *d h*, will be refracted to *e* and B, and, therefore, to an eye at H, the object C will appear in the direction H *e* E, and HBD, as well as that of H *i* C. The same thing will happen, if, instead of three, there be any number of flat surfaces.

QUESTIONS ON OPTICS.

What is Sir Isaac Newton's theory of light?

What is a *ray* or pencil of light?

What is a *beam* of light, and what a *pencil* of *rays*?

What is a transparent *medium*?

What substances are called *opaque*?

What is the difference between *diverging* and *converging* rays?

What is the *radiant point*?

What is the *focus*?

When is a ray of light said to be *inflected*, when *reflected*, and when *refracted*?

What is said concerning the emission of particles of light in all directions?

What is the rate of velocity with which light moves?

How is it proved that the particles of light (if they are particles,) are extremely small?

What is the rule for estimating the quantity of light emitted by a luminous body?

Give an example of this rule.

Explain the diagram illustrating the *divergency* and *parallelism* of the rays.

What happens when a ray of light passes out of a rarer into a denser medium?

When a ray passes obliquely from a *rarer* to a denser medium, which way in regard to a perpendicular is it refracted?

When a ray passes out of a denser into a *rarer* medium, which way is it refracted?

Illustrate these laws by a sketch.

What is meant by the angle of *incidence*, and what by the angle of reflection?

Describe the various kinds of lenses.

What is the axis of a lens?

If parallel rays fall upon a *plano-convex* lens, what then?

What is meant by *focal distance*?

What is the rule for finding the *focal distance* of a *plano-convex* lens?

How do you find the focal distance of a *double convex* lens?

What proportion is there between the heat of the focus of a glass and the heat of the sun itself?

What kind of a lens is a common burning-glass?

Explain and illustrate proposition 164.

Explain fig. 46, illustrating proposition 165.

What are the principal phenomena of the rays in connection with the various lenses?

What difference in quantity is there between the angle of *incidence*, and that of *reflection?*

How does Sir Isaac Newton explain the cause of reflection?

What are the chief phenomena of reflected rays?

How many coats are proper to the eye, and what do they enclose?

What are the names of the coats, and how are they situated in respect to each other?

Mention the names of the humours.

Where is the sense of vision situated?

Prove that the images of objects are painted on the retina in an inverted position.

How is it proved that these images are the cause of vision?

What causes dimness of sight in old age?

What is the cause of short-sightedness?

Explain proposition 175.

How do we judge of the distance of an object?

Are all the rays of light *refractible* or *reflexible* alike?

Explain the reason why they are not.

When is light called *homogeneous?* and when *heterogeneous?*

What are the colours produced by homogeneous rays called?

What are those produced by heterogeneous rays called?

How is a ray of light separated into its primary colours?

What are the colours of the spectrum, and in what order do they succeed each other?

What is said of the colours of homogeneous light?

How are the various colours accounted for?

What colour is the colouring matter of various substances, as the leaves of trees, &c.?

What is the cause of the rainbow?

Illustrate by a diagram, how the light is refracted and reflected to produce the rainbow?

What produces the secondary rainbow?

What is the *mirror* or *speculum?*

How do *concave* glasses assist the sight?

How do *convex* glasses assist the sight?

Why do small objects appear larger under the microscop than with the naked eye?

What laws govern the magnifying power of the microscope

How many kinds of microscopes are there?

Describe each, and the method of using them.

By what rules are the magnifying powers of each of thes instruments estimated?

Point out the difference between the *refracting* and *reflect ing* telescope.

What is the sole business or effect of telescopes?

Explain why the image of an object is seen through th telescope under an enlarged angle.

Explain and illustrate proposition 193.

How many eye-glasses have telescopes which shew object in their natural positions?

Explain the difference between the several telescopes de scribed.

What are the dimensions of the several parts of Dr. Her schel's grand telescope?

What is the principle of the *camera obscura?* Describe it operation and use.

What is the *magic* lantern?

Point out the principle of its construction, and describe it effect.

What is the *phantasmagoria?*

Describe the multiplying-glass.

OF ASTRONOMY.

201. Astronomy is the science which teaches th motions of the Earth, the Sun, Moon, Planets, Comet and Stars, and explains the phenomena occasioned b those motions.

Obs. 1. The student in the day time may observe one of th chief of these motions in the rising, ascent, exaltation, de clension, and setting of the sun. In the morning he will se it rise in the eastern part of the heavens, ascend in this he misphere towards the South, attain its greatest height at noo and then descend again, till it sets in the West, as far fro the South as it rose in the morning. This is the *first* practic lesson in Astronomy.

2. In the night time he may observe the stars rise and set in the East, ascend towards the South, and decline and set to the West; and this will be the *second* lesson.

3. He may, however, observe that one star, viz, that over the North Pole, never moves, and that all the others move around it, and those within a certain distance never set; and, in short, in this *third* lesson, which is worthy of being pursued through successive evenings, he will become master of the general motions of the heavens.

4. He will observe, in a *fourth* lesson, what is also to be pursued through successive nights, that the moon changes its place with regard to the stars, that she increases in light in proportion to her increased distance from the sun, till she arrives at the opposite, or rises as the sun sets; and that the light increases on one side, and decreases on the other, being always towards the sun.

5. He will in like manner observe, that the planets change their motions slowly in regard to the fixed stars, and that both moon and planets move in the same line, or nearly so, among the fixed stars; and this *fifth* lesson may be mixed with others through successive weeks.

5. He will be highly gratified by applying any telescope, (the larger the better, but the smallest will afford much gratification,) to the moon, planets, and stars. He will observe the decrease and increase, and change of the shadows of the Moon's pits; the satellites of Jupiter; the Moon-like appearance of Venus; the ring and moons of Saturn; and many of the constellations and nebulous stars.

7. By mixing such observations on the heavens and heavenly bodies, with the results given in the following paragraphs, of observations made during many thousand years, the student will soon become expert in this most sublime of all the sciences.

202. The *Solar System* consists of the Sun ☉ in the centre:

Of seven *primary planets*, Mercury ☿, Venus ♀, the Earth ⊕, Mars ♂, Jupiter ♃, Saturn ♄, Herschel ♅:

Of four *Asteroids*, or minor planets, Ceres ⚳, Pallas ⚴, Juno ⚵, and Vesta ⚶:

Of eighteen *secondary planets*, the Earth's Moon, Jupiter's four Satellites, Saturn's seven, and six belonging to Herschel:

And of a considerable number of Comets.

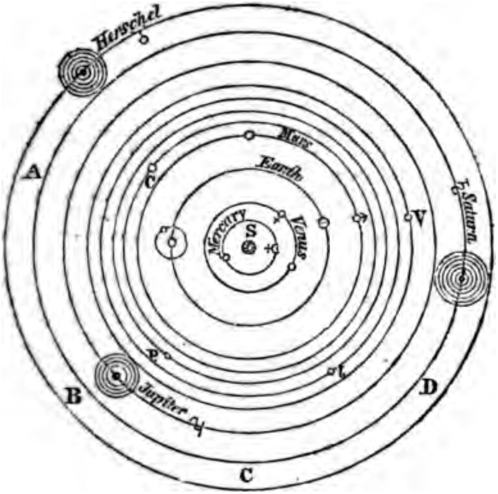
Obs. 1. PTOLEMY supposed the earth to be perfectly at rest, and the sun, moon, planets, comets, and fixed stars, to revolve about it every day; and that, besides this diurnal motion, the sun, moon, planets, and comets, had a motion in respect to the fixed stars, and were situated, in respect to the earth, in the following order: the Moon, Mercury, Venus, the Sun, Mars, Jupiter, Saturn.

2. The system received by the Egyptians was, that the earth was immoveable in the centre, about which revolved, in order, the Moon, Sun, Mars, Jupiter, and Saturn; and about the Sun revolved Mercury and Venus. This disposition will account for the phases of Mercury and Venus, but not for the apparent motions and retrogradations of Mars, Jupiter, Saturn, and Herschel.

3. In the system of Tycho Brahe, a Danish nobleman, the earth is placed immoveable in the centre of the orbits of the sun and moon, without any rotation about its axis; but he made the sun the centre of the orbits of the other planets, which therefore, revolved with the sun about the earth.

4. The system which is now universally received is called *the Copernican*, or *Solar System*. It was taught by Pythagoras, 500 years before Christ; and afterwards rejected, till revived by Copernicus, in the sixteenth century. In this system the Sun is placed in the centre of the system, about which the planets revolve from west to east, in the following order: Mercury, Venus, the Earth, Mars, Jupiter, Saturn, and the Herschel planet: beyond which, at immense distances, are placed the fixed stars. The Moon revolves round the earth; and the earth turns about its axis. The other secondary planets move round their respective primaries from west to east, at different distances, and in different periodical times.

5. In the fig. the SOLAR SYSTEM is represented. S is the Sun in the centre, surrounded by circles, representing in succession the orbits of Mercury, Venus, the Earth and Moon, Mars, the four Asteroids; C Ceres, P Pallas, J Juno, V Vesta, Jupiter and his four Moons, Saturn, his ring, and seven moons, and Herschel and his six moons. The student will find it a pleasant exercise to draw the system on larger paper, in which the distances should be in exact proportion.



6. There are several ways of demonstrating that the planets move round the sun; one or two of which shall be mentioned: thus Mercury and Venus always appear in the neighbourhood of the sun, and therefore, if the sun revolved round the earth as a centre, so must those planets; but if they did, then the motion of each would always appear to the inhabitants of the earth nearly equable, and in the same direction; whereas now they are sometimes stationary, or appear to have no proper motion: sometimes they move eastward in reference to the fixed stars, and their motion is then called direct, progressive, or *in consequentia;* sometimes they move westward, or have a retrograde motion, and are then said to move *in antecedentia:* all which appearances are necessary when we admit the sun to be the centre of their orbits and of the earth's, but wholly irreconcilable with any other hypothesis.

Also, when Mercury and Venus appear in conjunction with the sun, they are sometimes hid behind the body of the sun, and sometimes pass between it and the earth, appearing like a dark

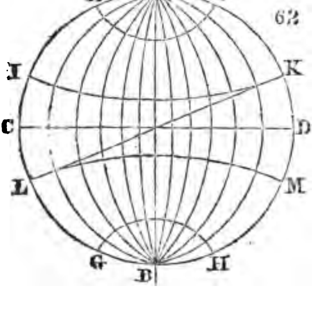
spot on the sun's disc or face; but if they have latitude, when in its superior conjunction, that is, when beyond the sun, they shine with a face perfectly circular, like a full moon. But the face disappears in its inferior conjunction, that is, when it is between us and the sun, as the moon does at her change; whence it is evident that their orbits are between the sun and the orbit of the earth. Mars sometimes appears in opposition to the sun, which proves that its orbit includes that of the earth; and that it includes the Sun is plain, otherwise Mars would in its conjunction with the Sun disappear, like Mercury and Venus, which never happens: the same may be observed of Jupiter, Saturn, and Herschel.

7. The motions of the earth in its orbit are proved, by the effect of its motion on the apparent motions of the several planetary bodies. These, as the earth happens to be situated, become stationary, retrograde, or direct, and the variations are exactly measured by motions referred to the earth, like the motions of objects ashore, when we are moving in a boat.

203. The earth is of a globular form, because,

1. The shadow of the earth projected on the moon in an eclipse is always circular.—2. The convexity of the surface of the sea is visible; the mast of an approaching ship being seen before its hull.—3. The north polar star becomes more elevated by travelling northward in proportion to the space passed over.—4. Navigators, by steering their course continually westward, arrive again at the place from whence they departed.

DEFINITIONS RELATING TO THE TERRESTRIAL GLOBE.



Obs. The *axis* of the earth is an imaginary line passing through the centre north and south, about which the diurnal revolution is performed. It is represented by the line between A B, fig. 62.

2. The *Poles* of the earth are the extremities of this axis, A B.

3. The *Equator* C D, is an imaginary line passing round the earth east and west, at equal distances from the poles.

4. The small circle E F, is called the *Arctic circle;* the circle G H, is called the *Antarctic circle.*

5. The circle north of the equator I K, is called the *tropic of Cancer*, that south of the equator L M, the *tropic of Capricorn.*

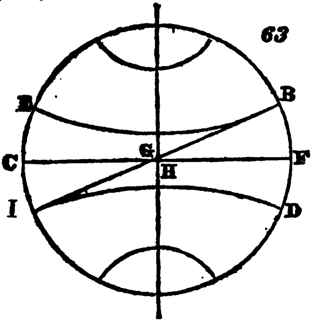
6. The spaces between the ends north and south of the equator are called *zones;* that space between the tropics is called the *torrid zone;* between the tropics and the polar circles are called the *temperate zones*, and north of the arctic and south of the antarctic circles are called the *frigid zones.*

7. Latitude is distance north or south of the equator; longitude is distance east or west measured upon the equator, from any assumed point.

Astronomical circles, whether larger or smaller, are divided into 360 degrees: the length of a degree of course depends upon the magnitude of the circle; a degree on the earth is about 69 1-2 miles.

DEFINITIONS RELATING TO THE CELESTIAL GLOBE.

Obs. 1. The surface of the Celestial Globe represents the internal surface of the imaginary hollow sphere of the heavens. The lines and figures on the globe are of course imaginary.



2. The line E B, is the *tropic of Cancer.* The line I D, is the tropic of *Capricorn.* The sun never goes north of Cancer nor south of Capricorn.

3. The line C F, is the *Equator* or *Equinoctial line.*

4. The line B I, is the *Ecliptic*, and indicates the path that the sun appears annually to pursue in the heavens. It is divided into 12 equal parts, called signs of the zodiac.

5. The points at which the ecliptic cuts the equator G H, are called the *equinoctial points.*

6. Those two points of the ecliptic farthest from the equator are called *Solstices.*

7. That space in the heavens about 16 degrees in width through the middle of which passes the ecliptic, is called the *zodiac.*

8. The *latitude* of a heavenly body is distance from the ecliptic: *longitude* is distance from the first degree of Aries.

9. The *sensible Horizon* is an imaginary circle, which appears to touch the surface of the earth, and separate the visible part of the heavens from the invisible. The *rational Horizon* is a circle parallel to the former, the plane of which passes through the centre of the earth, and cuts the heavens into two equal hemispheres.

10. The *Poles* of the *Horizon* are two points, the one of which, over the head of the spectator, is called the *Zenith*; the other, which is under his feet, is called the *Nadir*.

11. A circle which passes from north to south through the zenith of any place is called a *Meridian*, and is said to be the meridian of that place. The meridian of any place passing through the poles, and falling perpendicularly upon the horizon, cuts it in two opposite cardinal points, called *North* and *South*.

12. The *Altitude* of any heavenly body above the horizon is the part of a vertical circle intercepted between the body and the horizon, or the angle at the centre of the earth measured by that arc.

13. The *Azimuth* of a heavenly body, is the arc of the horizon intercepted between the meridian and a vertical circle passing through that body; it is eastern or western as the body is east or west of the meridian.

14. The *Amplitude* of a heavenly body at its rising or setting, is the arc of the horizon intercepted between the point where the body rises, and the east or west.

15. The *Declination* of any heavenly body, is its distance from the equator; and is either northern or southern.

16. The *Right Ascension* of any heavenly body is its distance from the first of Aries reckoned upon the equator.

17. A planet's place, as seen from the sun, is called its *Heliocentric* place, and as seen from the earth, its *Geocentric* place.

18. Two planets are said to be in *Conjunction* with each other, when they have the same longitude, or are in the same degree of ecliptic on the same side of the heavens, though their latitude be different. They are said to be in *Opposition* when their longitudes differ half a circle, or they are in opposite sides of the heavens.

19. The celestial sphere is called *right*, *oblique*, or *parallel*, as the equator is at right angles, oblique, or parallel to the horizon.

204. As the earth revolves round its axis daily from *west to east*, the heavenly bodies appear to a spectator on

the earth to revolve in the same time from east to west, and the alternate succession of day and night is the effect of the revolution of the earth towards and from the sun.

Obs. For all the heavenly bodies appearing to move from east to west, while the earth revolves from west to east, the sun will appear, in each revolution, to rise above the horizon in the east, and after describing a portion of a circle, to set in the west, and will continue below the horizon, till, by the revolution of the earth, it again appears in the east; and thus day and night is alternately produced.

205. As the earth revolves round the sun in 365 days, 6 hours, 56 minutes, 4 seconds, the sun appears to revolve round the earth in the same time, but in the contrary direction.

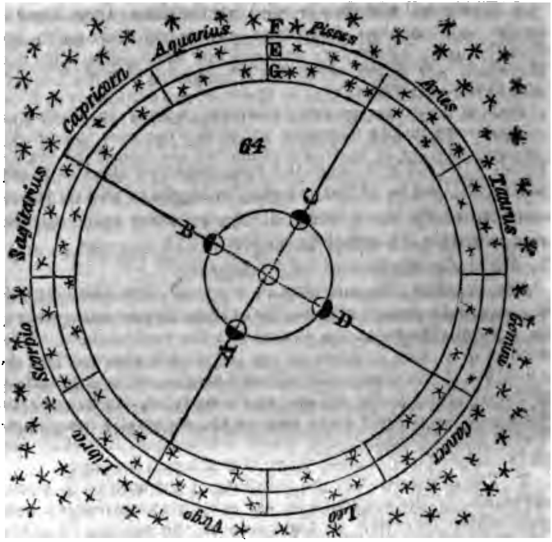
Obs. 1. It is manifest that the circle in which the sun appears to move, is the same in which the earth would appear to move, to a spectator in the sun. Hence the apparent place of the sun being found, the true place of the earth in its orbit is known to be 180° distant.

2. The orbit in which the earth revolves round the sun is not a circle but an ellipse, having the sun in one of its foci.—For the computations of the sun's place, upon this supposition, allowing for the disturbing forces of the planets, are found to agree with observations.

206. The stars round the Zodiac are classed in 12 *Signs:* Aries, Taurus, Gemini, Cancer, Leo, Virgo, Libra, Scorpio, Sagittarius, Capricorn, Aquarius, Pisces.

Obs. 1. The names and characters of the signs are, Aries, ♈ ; Taurus, ♉ ; Gemini, ♊ ; Cancer, ♋ ; Leo, ♌ ; and Virgo, ♍ ; all *northward* of the equator.

Libra, ♎ ; Scorpio, ♏ ; Sagittarius, ♐ ; Capricornus, ♑ ; Aquarius, ♒ ; and Pisces, ♓ ; are *southward* of the equator.



2. The circle E, fig. 64, represents that circle in the heavens in which the sun appears to move, called the *ecliptic*.

3. The circles F G, represent the broad belt or circle in the heavens occupied by the 12 constellations called the *zodiac*.

4. The signs of the zodiac are clusters of stars, and are represented by figures drawn on the celestial globe. They are so situated that the earth in its annual revolution passes directly between them and the sun.

The Sun as he appears to move round in the ecliptic, seems to enter these clusters of stars, and is therefore said to be in this or that sign or constellation. Thus, if a right line, fig. 64, be drawn from the earth passing through the sun till it reaches one of the constellations, the sun is said to be in that constellation in which the line terminates. Thus when the earth is at A, the sun is in the constellation, or sign Aries; when the earth is at B, the sun is in Cancer; when the earth is at C, the sun is in Libra; when the earth is at D, the sun is in Capricorn.

5. The pupil will bear in mind that the observation founded on the idea that the sun and stars revolve round the earth, are founded upon *appearance only* and not upon *facts*. He will therefore not forget while he is imagining that the heavens move around the earth that in fact they are stationary as it respects the earth, and it is the earth that moves round the sun.

207. The axis of the earth in every part of the earth's revolution about the sun, makes with the plane of its orb, that is, of the ecliptic, an angle of 66½ degrees, consequently the planes of the equator and ecliptic, make with each other an angle of 23½ degrees nearly, being the compliment of 90 degrees.

Obs. 1. The obliquity of the ecliptic is not permanent, but is continually diminishing by the ecliptic approaching nearer to a parallelism with the equator, at the rate of about half a second in a year, or from 50″ to 55″ in 100 years.—The inclination at this time is 23° 27′ 46″ nearly. The diminution of the obliquity of the ecliptic to the equator, is owing to the action of the planets upon the earth, especially the planets Venus and Jupiter. The whole diminution, it is said, can never exceed one degree, when it will again increase.

2. The diminution of the obliquity of the ecliptic is a consequence of the approach of the earth's axis towards a perpendicular direction to the plane of the ecliptic; but the earth's axis has, besides the progressive motion, a tremulous one, by which its inclination to the plane of the ecliptic varies backwards and forwards some seconds; the period of these variations is nine years. The tremulous motion is termed the nutation of the earth's axis. Both these motions of the terrestrial axis are occasioned by the action of the sun, moon, and planets, on the earth.

208. The difference of longitude at two places may be found by observing, at the same time from both places, some simultaneous appearance in the heavens.

Obs. If the eclipse of Jupiter's innermost satellite, on the very instant of its immersion into the shadow of Jupiter, be observed by two persons at different places, it will be seen by both at the same instant. But if this instant, with reference to the day, be half an hour, for example, sooner at one place than at the other, because the places differ half an hour in their reckoning of time, their difference of longitude must be 70° 30′; because the whole 360° are equal to 24 hours, and consequently every 15° are equal to an hour.

209. **Those who live on opposite sides of the earth, but in the same parallel of latitude, have opposite hours of the day, but the same seasons.**

Obs. Being both on the same side of the equator and at the same distance from it, when the sun's declination makes it summer or winter in one of the places, it will be the same at the other; but because they are distant from each other 180° of longitude, when it is noon at one place, it is midnight at the other; these are called *Periœci.*

210. **Those who live in opposite parallels of latitude, but under the same meridian, have opposite seasons of the year, but the same hour of the day.**

Obs. When the sun has declination towards the north pole, it will be summer to those who live in the northern parallel of latitude, and winter to those who live in the southern parallel of latitude. But having the same longitude, their hours of the day will be the same; these are called *Antœci.*

211. **Those who live in opposite parallels of latitude and opposite semicircles of the meridian, have opposite seasons of the year, and opposite hours of the day.**

Obs. 1. Because they are in opposite latitudes, they will have opposite seasons; and because they are in opposite semicircles of the meridian, they will have noon when it is midnight at the other place; these are called *Antipodes.*

2. These and many other propositions will be better understood by means of the problems on the Globes and Maps, to be found in *Goldsmith's Grammar*, and his *Royal Atlas.*

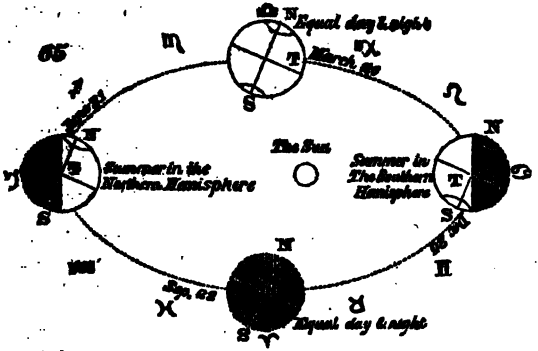
212. **The axis of the earth, in its circuit round the sun, being inclined to the plane or level of its orbit, this inclination occasions the succession of the four seasons.**

Obs. 1. The earth's axis makes an angle of 66° 32′ with its orbit, that is, with the ecliptic, and always preserves its parallelism, or is directed towards the same point, at an infinite distance, in the heavens; hence during one half of the year the north pole is continually illuminated by the sun, and the south pole is all that time in darkness: and during the other half of the year, the south pole is constantly in the light, and the north pole is in darkness: and other parts in a proportional degree partake of this vicissitude, and create the variety of the seasons.

2. The difference in the degrees of heat, is owing chiefly to *the different heights* to which the sun rises above the horizon

and the different length of the days. When the sun rises highest in summer its rays fall less obliquely, and consequently, more of them fall on any given portion of the earth's surface than in winter, when the rays fall obliquely; and when the days are long, and the nights short, the earth and air are more heated in the day than they are cooled in the night, and the reverse when the days are short and the nights long.

65



Illus. The lengthening and shortening of the days, and the different seasons, are produced by the motion of the earth T, fig. 65, in its orbit round the sun S. The axis of the earth N S inclines to the plane of the orbit, and is parallel to itself in all parts of the orbit. In June the north pole N inclines to the sun, and it is summer in the northern parts of the earth; in December the north pole declines from the sun, and it is winter in the northern and summer in the southern hemisphere.

212. The orbit in which the earth revolves about the sun, is not a circle but an ellipsis or oval.

Obs. 1. The sun's diameter being on the thirty-first of December 31′ 45″, and on the second of July 32′ 45″, or nearly one thirtieth longer, and consequently so much nearer, and increasing and decreasing gradually, it is evident the orbit of the earth is an ellipsis. Newton found the mean diameter of the sun, to be 32′ 12″, but as above it is 32′ 15″.

2. In January therefore, the earth is in its *perihelion*, and in July in its *aphelion*, and having a smaller circle to traverse in

its perihelion-half than its aphelion-half, it is eight days longer in performing the aphelion-half of its orbit than the perihelion-half.

3. The motion of the aphelion point is 1° 44′ in 100 years; so that it will pass round the ecliptic in 20700 years.

4. In the perihelion, the earth moves in its orbit 61′ 11″ per day, and in the aphelion, but 57′ 10″, being one-fifteenth less. Its mean daily motion is 59′ 10 1-2″.

214. Twilight is occasioned by the atmosphere above the horizon reflecting rays of the sun, when the sun itself is below the horizon.

Obs. 1. When the sun is at any point below the horizon, it cannot be directly seen by a spectator. But, because rays from the sun can pass to the part of the atmosphere above the head of the spectator, this part of the atmosphere will be illuminated before the sun rises, or after it sets, and will become visible by reflection to the spectator; that is, *twilight* will be produced.

2. It is entirely owing to the reflection of atmosphere that the heavens appear bright in the day time. For without it, only that part would be luminous in which the sun is placed; and if we could live without air, and should turn our backs to the sun, the whole heavens would appear as dark as in the night. In this case also we should have no twilight, but a sudden transition from the brightest sunshine to dark night immediately upon the setting of the sun.

3. The *twilight* is longest in a parallel sphere, and shortest in a right sphere: and in an oblique sphere, the nearer the sphere approaches to a parallel, the longer is the twilight, because twilight lasts till the sun is eighteen degrees perpendicularly below the horizon.

215. The atmosphere also refracts the sun's rays in such a manner, as to bring him into sight, every clear day before he rises in the horizon, and to keep him in view for some minutes, after he is really set below it. The effect of this refraction is about six minutes of time, or 33′ of space, being rather more than the diameter of the sun or moon.

Obs. From the same cause, the heavenly bodies appear higher than they really are, so that to bring the apparent altitudes to the true ones, the quantity of refraction must be subtracted. The higher they rise the less are the rays refracted.

and when the heavenly bodies are in the zenith, they suffer no refraction.

216. A *Natural day* is the time the sun takes in passing from the meridian of any place, till it comes round to the same meridian again; but the natural days are not equal to one another: and the *Equation* of time, is the difference between the mean length of the natural day (or 24 hours) and the length of any single day measured by the sun's motion, or between *mean time* and *apparent time*.

Obs. 1. For any natural day is the time in which the earth performs one revolution round its axis, and such a portion of a second as is equal to the sun's increments of right ascension for that day; but the sun's daily increments of right ascension are unequal; therefore the additional portion of the second revolution will sometimes be greater and sometimes less, and consequently, the times in which the natural days are completed will be unequal.

2. If the sun were to move uniformly round the equator in the same time in which it appears to describe the ecliptic, its apparent daily motion would be a measure of mean time. For the natural days in that case being liable to no variation, either from the inclination of the sun's orbit, or the irregularity of its motion, must be equal.

OF THE SUN ☉.

217. The sun is a spherical body, situated near the centre of gravity of the system of planets of which our Earth is one; its diameter is 877547 English miles; and it revolves round its axis in 25 days and 10 hours.

Obs. 1. From several phenomena it is concluded that there is an atmosphere which environs the sun, and extends to a considerable distance from it. It seems likely also that its light and heat are created by gaseous combustion. Euler makes the light equal to 6500 candles at a foot distance, while the moon would be as one candle at 7 1-2 feet; Venus at 421 feet; and Jupiter at 1320 feet. Consequently the sun would appear like Jupiter at 130,000 times his present distance.

2. The period of the sun's revolution about its axis has been determined by means of several dark spots of various figures, which may commonly be seen with telescopes; in the same

manner have the periods of the revolution of Mars, Venus, and Jupiter, about their axes, been determined; whence it is inferred that this motion is general, and belongs to all the planets.

3. In the year 1779, there was a spot on the sun, which was large enough to be seen by the naked eye. It was divided into two parts, and must have been 50,000 miles in diameter. Dr. Herschel supposes, that the spots in the sun are mountains on its surface, which he thinks may be more than 300 miles high. He examined the sun with several powers from 90 to 500, and it appeared, that the black spots are the opaque ground or body of the sun; and that the luminous part is an atmosphere, which, being intercepted or broken, gives us a glimpse of the sun itself.

4. He concludes, that the sun has a very extensive atmosphere, which consists of elastic fluids that are more or less lucid and transparent; and of which the lucid ones furnish us with light. This atmosphere, he thinks, is not less than 1843, nor more than 2765 miles in height; and he supposes that the density of the luminous solar clouds need not be greater than that of our aurora borealis, to produce the effects with which we are acquainted.

5. If one of these spots appears upon the eastern limb or edge of the sun's disc, or face, it moves from thence towards the western edge in about 13 1-2 days. Here the spot disappears; and in about 13 1-2 days more, it is seen again upon the eastern edge; and so continues to go round, completing its revolution in 27 days; during one half of which time we see it on the disc of the sun, and during the other half it disappears.

6. The quantity of matter in the sun, is to that in Jupiter nearly as 1100 to 1, and the distance of that planet from the sun, is in the same ratio to the sun's semi-diameter; consequently, the centre of gravity of the sun and Jupiter is nearly in the superfices of the sun.

7. By the same method of calculation, it will be found, that the common centre of gravity of all the planets cannot be more than the length of the solar diameter distant from the centre of the sun.

8. The sun's diameter is equal to 100 diameters of the earth, and therefore its cubic magnitude must exceed that of the earth one million of times: and its mass is 329,620 times that of the earth, therefore, the sun would move but one foot by the action of the earth, while the earth would move 329,620 feet by the action of the sun.

9. Its similarity to the other globes of the solar system, is

solidity, atmosphere, surface diversified with mountains, and valleys, and rotation on axis, lead us to suppose, that it is most probably inhabited, like the rest of the planets, by beings whose organs are adapted to their peculiar circumstances.

10. Though it may be objected, from the effects produced at the distance of 95,000,000 miles, that every thing must be scorched up at its surface, yet many facts shew that heat is produced by the sun's rays only when they act on a suitable medium; or when radiated and reflected by suitable surfaces. On the tops of mountains of sufficient height, we always find regions of ice and snow; though if the solar rays themselves conveyed all the heat we find on this globe it ought to be the hottest where their course is the least interrupted.

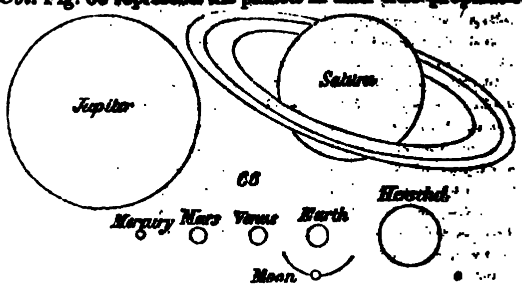
11. If we are to consider all light as analogous, from its equal powers on the eye, it seems likely that the light and heat of the sun are occasioned by the combustion of gas in the upper regions of its atmosphere, not dissimilar perhaps, to the combustion of carburetted hydrogen gas, with which we have lately illuminated our streets and houses. The simultaneous production of light and heat, seems in truth, in all cases to be produced by the combustion of gas.

12. Dr. Herschel conceives the sun and planets to have a general motion at the rate of the earth's motion in its orbit, with relation to the fixed stars; but at this rate, if the distance of the stars is 200,000 times that of the diameter of the earth's orbit, the sun would be 60,000 years in moving over the distance of the nearest fixed star.

OF THE PRIMARY PLANETS.

218. The primary Planets are those which regard the sun as their proper centre. The number already known is seven: Mercury, Venus, the Earth, Mars, Jupiter, Saturn, and Herschel.

Obs. Fig. 66 represents the planets in their true proportion.



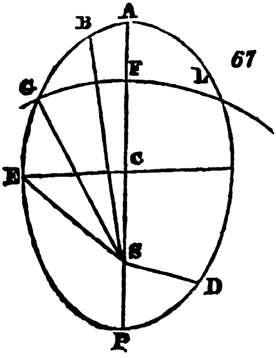
66

219. Four small telescopic planets, called *Asteroids* have lately been discovered between the orbits of Mars and Jupiter; called Ceres, Juno, Pallas, and Vesta.

ELEMENTS OF THE PLANETS.

DEFINITIONS.

1. The sun being placed in the focus of the elliptical orbit of a planet, the planet cannot always be at the same distance from the sun; but will be farthest from it when in the extremity A of the greater axis, most distant from the focus S, in which the sun is; and nearest to it when in P.



67

The point A is termed the HIGHER APSIS, or the APHELION; and the point P, the LOWER APSIS, or the PERIHELION: these points are constantly varying, and their motion in a century, is called the *secular* motion.

The distance between the centre of the ellipse C, and the sun or focus S, is called EXCENTRICITY.

The greater axis A P, is the LINE of APSIDES.

The straight line S E, drawn from the extremity of the less axis E C to the sun, is the MEAN DISTANCE of the planet from the sun.

The mean distance added to the excentricity is equal to the APHELION DISTANCE.

And the mean distance less by the excentricity is equal to the PERIHELION DISTANCE.

When the sun or moon is at the greatest distance from the earth, it is said to be in its APOGEE; and when at the least distance, in its PERIGEE.

2. A planet does not proceed in its orbit with an equable motion; but in such a manner, that a line drawn from the sun to the planet, describes an *area* always proportionate to the time. For example, suppose a planet to be in A, whence in a certain time it arrives at B; the space or *area* which the line S A, called the RADIUS VECTOR, describes, is the triangle ASB. Supposing the planet to be in P, let the straight line SD be so drawn that the area PSB may be equal to the area ASP; then the planet will move through the arcs AB and PD in equal times, though these arcs are unequal, being nearly to each other reciprocally as their distances from the sun; for the areas being equal, the arc PD is as much in proportion greater than the arc AB, as SP is less than SA.

3. A planet's ANOMALY is its distance from the aphelion. When a planet is supposed to move in a circle in the centre of which is the sun, the portion FG of the circle bears the same ratio to the whole circumference, that the time since the planet passed its aphelion does to the time of its whole revolution, and is termed the MEAN ANOMALY. If the elliptical orbit of a planet be so divided that the area ASG shall have the same ratio to the whole ellipse ABED, which the time since the planet passed its aphelion, has to its whole period, then is the angle ASG the measure of the planet's distance from the aphelion, at the time the planet is in G; this angle is called the TRUE ANOMALY. The difference between the mean anomaly, and the true anomaly, is called the EQUATION of the *Planet's Centre.*

4. When the motion of a planet is reckoned from the equinoctial point, it is called its LONGITUDE. There are tables of each planet's mean motion, and of the equation of its centre, with its relative distance from the sun, and its latitude in any part of its orbit; whence its true place may be calculated at any time.

5. Let SG be a mean proportion between the semi-axis major CA, and the semi-axis minor CE, then, when the planet comes to the point G or L, the equation of its centre will be the greatest, and this GREATEST EQUATION varies according to the excentricity of the orbit. The points G and L may be found by observation, and as A lies equally between them, the aphelion may from them be determined.

6. A planet ELONGATION, or its angular distance from the sun, is a e formed at the earth by two lines, one drawn from the to the sun, and one from the earth to the planet.

7. A p PERIODIC TIME, or the time it takes in a revolution the sun, is found by observing when it is in *any* point of i it, and after any number of revolutions, observing w comes to the same point again: that interval of time di by the number of revolutions, gives the time of one. is called a TROPICAL REVOLUTION; but as while th et is making this revolution, the equinoctial point is n by the precession of the equinoxes, there will be an add l time required for the planet to move, before it will be with, when the former observatio e, the SIDEREAL REVOLUTION, in to the same star, exceeds the

8. A pe will perceive that a planet will appea in the order of the signs, or DIRECT, and sometimes ary direction, or RETROGRADE, and to be sometimes TIONARY. An inferior planet's motion is *direct* through uperior conjunction, and *retrograde* through its inferior; between which situations it is *stationary*. A superior planet is *retrograde* when in opposition to the sun, and *direct* when in conjunction with it; and between those situations it is *stationary*.

9. The planes or levels of the planet's orbits are variously inclined to that of the ecliptic. The opposite points in which the plane of an orbit *crosses* the plane of the ecliptic, are called NODES: that at which the planet rises north of the ecliptic, is called the *ascending node*, and the other the *descending node*. The line which joins the nodes, passing through the sun, is called the *line of the nodes*.

OF MERCURY ☿.

220. The diameter of this planet is 3180 miles.

Its sidereal revolution 87d. 23h. 15′. 44″.

Longitude, January 1st, 1815,	8s.	23°	25′.	
Annual Motion . .	1	23	43	3
Aphelion Place	8	14	22	0
Secular motion of aphelion .		1	33	45
Ascending node	1	16	4	1
Secular motion of the node .		1	12	10
Inclination of orbit . .		7	0	0
Greatest equation . .		23	40	0
Excentricity in miles . .				7,434,424

Relative mean distance from the sun	38710
Mean distance in miles	36,841,468

Obs. 1. The *greatest elongation* of Mercury from the sun being but 28° 20′ it is mostly above the horizon when the sun is; and, therefore, is seldom seen. When it is visible it is in the east just before sun-rise, or in the west soon after sun-set, accordingly as its place follows or precedes that of the sun.

2. When viewed with a telescope, it appears with phases similar to the moon. When in its inferior conjunction, if its latitude be less than the semi-diameter of the sun, it passes over the sun's face; this is called a transit of Mercury.

3. The density of the sun's heat, which is in the same proportion as his light, is seven times as great in Mercury as with us; so that water there, would be carried off in the shape of steam: for by experiments with the thermometer, it appears that a heat 7 times greater than that of the sun's beams in summer, will serve to make water boil. This however depends on the weight of the atmosphere of Mercury.

OF VENUS ♀.

221. The diameter of this planet is 9498 miles,
It revolves round its axis in 23h. 20′.
Sidereal revolution 224d. 16h. 49′ 10″. 6.

Longitude, Jan. 1, 1815	9s.	11°.	45′.	
Annual motion	7	14	47	30
Aphelion	10	8	35	18
Secular motion of aphelion		1	21	0
Ascending node	2	14	57	18
Secular motion of node			51	40
Inclination of orbit		3	23	35
Greatest equation			47	20
Relative excentricity				498
Excentricity in miles				465387
Relative mean distance from the sun				72333
Mean distance in miles				68,891,486
The greatest elongation, is				47°.48′.

Obs. 1. When the elongation of Venus is 39° 44′ between its inferior conjunction and greatest elongation, it appears brightest; for then, though its phasis is but the 53.200ths of a

circle, it is so much nearer to the earth than in its superior conjunction, when it appears with a perfect disc, that the want of surface is more than compensated by the intenseness of the light: in that situation Venus is often seen by the unassisted eye in broad day-light.

2. Like Mercury, it sometimes passes over the sun's face, and its transit has been applied to one of the most important problems in astronomy, as by it, the true distances of the planets from the sun have been determined.

3. When Venus is to the west of the sun, it rises before the sun, and is called a morning star; this appearance continues about 290 days together; when this planet is to the east of the sun, it sets after the sun, and is called an evening star for about the same period, 290 days. Venus appears the brightest of the planets: it has a considerable atmosphere, and some astronomers assert, that they have discovered mountains on its surface.

OF THE EARTH ⊕.

222. The diameter of the earth is 7928 miles.
It revolves round its axis in 23h. 56′. 4″.
Sidereal revolution 365d. 6h. 9′. 11″. 5.

Longitude, Jan. 1st, 1815,	3s.	10°.	16′.	54″.
Aphelion	3	9	39	25
Secular motion of aphelion .		1	43	35
Greatest equation		1	55	36.5

Horizontal Parallax, or angle of its semi-diameter at the sun, . . 8″. 65″.

Inclination of axis, Jan. 1815,	. 23°. 27′. 46″. 4
Relative excentricity . . .	1681.395
Excentricity in miles . . .	1,571,285
Mean distance from the sun . .	95,173,127

223. In the daily revolution of the earth round its axis, the *centrifugal* force diminishes the weight of bodies more at the equator than in any other place on the surface of the earth, in the duplicate ratio of the semi-diameter to the cosine of the latitude of the place.

Obs. 1. As the earth revolves upon its axis, every place on its surface, except the two poles, describes a circle, the plane *of which is perpendicular* to the axis, and the radius of which *is the distance* of that surface from the axis.

2. Whence a body at the equator has its centrifugal force as much greater than a body between it and the pole, as the radius of the circle of the equator is greater than that radius; and universally, the centrifugal force at the equator, is to the centrifugal force at any other place on the surface of the earth, as the semi-diameter of the earth is to the cosine of the latitude of the place. And since it is manifest, that the gravity must be diminished as much as the centrifugal force is increased, the gravity of a body at the equator, is as much less than that of a body at any other place on the earth, as the semi-diameter of the earth is greater than the cosine of the latitude of the place.

3. It is found by calculation from this prop, that gravity at the equator is diminished by the centrifugal force, in the ratio of 288 to 289, and if the diurnal motion of the earth round its axis was about 17 times faster than it is, the centrifugal force would at the equator, be equal to the power of gravity, and all bodies there would entirely lose their weight. But if the earth revolved still quicker than this, they would all fly off.

4. Since a place in the equator describes a circle of 24,930 miles in 24 hours, it is evident that the velocity with which that place moves, is at the rate of 17.3 miles per minute. The velocity in any parallel of latitude decreases in the proportion of the cosine of lâtitude to the radius. Thus, for the latitude of London, say, as rad.: cos. 51°. 30′. :: velocity of the equator; velocity of London; by logarithms, as 10.00000: 9.794150 :: 1.232046 : 1.026196=10.6 miles; that is, London moves about the axis of the earth at the rate of more than 10 1-2 miles in a minute of time.

5. Lagrange calculates that the obliquity of the ecliptic has diminished 2000 years, and will diminish 2000 more, and Schubert determines its limits at 20° 34′ and 27° 48′. Its variation in a century is 50″. On January 1, 1815, it was 23° 27′ 46″ 4.

224. The earth is an oblate spheroid, elevated at the equator and depressed at the poles.

Obs. 1. It has been found by observation, that a pendulum, shorter by 2.169 lines, is required to vibrate seconds at the equator than at the poles; but the length of pendulums vibrating in the same time are as the gravities of the places where they vibrate; therefore the gravity at the poles is greater than at the equator. And it has been found by Sir I. Newton, that this difference of gravity is so much greater than would arise from the centrifugal force alone, that the ratio of the

equatorial di eter of the earth to the polar diameter, *must* be as 230 to , which makes the equatorial diameter *exceed* the pola ut 34 miles.

2. H ies near the poles are heavier than the same bodies t he equator; (1) Because they are nearer the earth's , where the whole force of the earth's attraction is accumulated (2) Because their centrifugal force is less on account of the diurnal motion being slower. For both these reasons, bodie carried from the poles towards the equator, gradually lose their weight

3. And the degrees of latitude upon the earth's surface are longer at the poles than at the equator. For an arc of a meridian near the p than near the equator; that is, it is an ar whence a degree measured upon that a than upon an arc of the same meridian at tl

225. The equi ve *in antecedentia*, or go backwards contrary to the order of the signs. lled the *precession of the equinoxes*, because it carries the equinoctial points forward in regard to the signs. And the *precession of the equinoxes* make the tropical year shorter than the periodical year.

Obs. If, while the sun moves in the order of the signs, the equinoctial point moves in the contrary direction, it is manifest, that the sun must arrive at the solstitial or equinoctial point from which it set out, before it arrives at the same place in the zodiac, or must complete the tropical year sooner than the periodical year The tropical year is observed to be 365 days, 5 hours, 49 minutes; the periodical year, 365 days, 6 hours, 4 minutes, 56 seconds.

226. The precession of the equinoxes is caused by the action of the sun and moon on that excess of matter about the equatorial parts of the earth, by which, from a perfect sphere it becomes an oblate spheroid.

Obs. 1. If the excess of matter at the equator be considered as a ring encompassing the earth at any distance, as Saturn is encompassed by its ring; if it be supposed that this ring moves round its centre, the same way in which the moon move round the earth; it is obvious that every point of this ring will be acted upon by the disturbing force of the sun in the same manner as the moon is acted upon. Particularly, the motion of the nodes of this ring, and con-

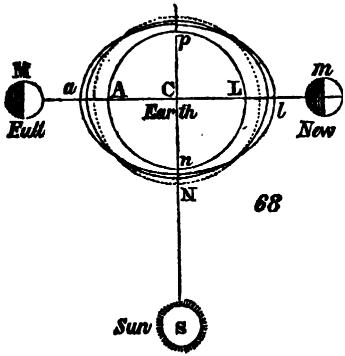
sequently, of the whole ring which moves with these nodes, and its inclination to the plane in which its centre moves will be affected in the same manner with the orbit of the moon: whence, its nodes when in syzygies will stand still, and its inclination will be greatest; but in all other situations, the nodes will go backwards, and fastest of all when in the quadratures, at which time the inclination of the ring will be the least. This will be the case whatever be the thickness of the ring, or its distance from the centre. If this ring be supposed to adhere to the earth, it is obvious that it will still have the motions described above, and that, in this situation, the earth itself must participate of these motions.

2. Hence the axis of the earth, being perpendicular to the plane of the equator, changes there with its incliuation to the plane of the ecliptic twice in every revolution of the earth about the sun. For instance, it increases whilst the earth is moving from the solstitial to the equinoctial, and diminishes as much in its passage from the equinoctial to the solstitial points: which phenomenon is called the nutation of the poles.

3. This precession of the equinoxes is found to be 50 seconds of a degree every year, westward or contrary to the sun's annual motion: so that with respect to the fixed stars, the equinoctial points fall backwards 30 degrees, in 2160 years, whence the stars will appear to have gone 20 degrees forward, with respect to the signs of the ecliptic, which are reckoned from the equinoctial point. Thus, the stars which were formerly in Aries, are now in Taurus, &c. This period is completed in 25,920 years.

4. The student should be aware that the precession of the equinoxes which merely changes the position of the stars with reference to the nodes on the earth's orbit, is different from the progression of the line of Apsides, or of the Aphelion or Perihelion points at the rate of 1° 44′ in a century, or round the ecliptic in 20700 years. Sir Richard Phillips, deduces from this motion, and from the varied action of the Sun in both hemispheres, a theory, by which he accounts for the present aggregation of water in the southern hemisphere, and concludes, that the same aggregation will take place in the northern hemisphere, when the Perihelion has its utmost northern declination.

227. There are two TIDES every twenty-four hours, and they are caused by the attraction of the moon and of the sun.



1. Let A*p*L*n* fig. 68, be the earth, and C it
dotted circle PN represent a mass of water c
face of the earth; let M, *m*, be the moon: S,
ferent situations. Because the power of grav
the squares of the distances increase, the wa
of the earth A are more attracted by the moo
central parts of the earth C, and the central
attracted than the waters on the opposite sid
L; consequently, the waters on the side L v
less than the centre, or will recede from ther
while the moon is at M, the waters will rise
on the opposite sides of the earth A,L; while, t
traction of the moon, the waters at P and N w

2. Or thus; because the moon and earth ar
volving about their common centre of gravity,
points A, C, L, describing circles about this c
the same periodical times, the forces acquired
these circles, will be to each other as their di
centre *a*A,*a*C,*a*L. Consequently, the point L
er force than C, and C than A, to retain it in
these points are retained in their respective cir
at M; and, consequently, the point L, which
and therefore requires the greatest force, is at
whilst A, the nearest point, is attracted the n
water about A being attracted too much, ar
too little, both will have their gravity diminish
of the moon, and will endeavour to leave the

the water at P and N, having their gravity increased by the same cause, will subside. Hence the form of the water on the surface of the earth will become an oblong spheroid.

3. This oval of waters keeps pace with the moon in its monthly course round the earth; while the earth, by its daily rotation about its axis, presents each part of its surface to the direct action of the moon, twice each day, and thus produces two floods and two ebbs. But because the moon is in the mean time passing from east to west in its orbit, it comes to the meridian of any place later than it did the preceding day; whence the two floods and ebbs require nearly 25 hours to complete them. The tide is at the greatest height, not when the moon is in the meridian, but some time afterwards, because the force by which the moon raises the tide continues to act for some time after it has passed the meridian.

4. As the moon thus raises the water in one place, and depresses it in another, the sun does the same; but in a much less degree, on account of the small ratio of the semi-diameter of the earth to the distance of the sun; for, as it was shewn of the moon, that the force of the sun by which it disturbs its motion is as the distance of the moon from the earth to that of the sun from the same, so, in this case, the force of the sun to disturb the waters is as the semi-diameter of the earth to the distance of the sun, which ratio is very small.

228. The tides are greatest at the new and full moons, and least at the first and last quadratures, and the highest tides are near the time of the equinoxes.

When the moon is in conjunction or opposition with the sun, as M, *m*, S, the tides which each endeavours to raise are in the same place; whereas, when the moon is in the first or last quarter, the sun being in the meridian when the moon is in the horizon, as M, Q, depresses the water where the moon raises it; whence the tides are then the least of all. On the full and new moons, which happens about the equinoxes, when the luminaries are both in the equator or near it, the tides are the greatest of all: for first, the two eminences of water are at the greatest distance from the poles, and hence the difference between ebb and flood is more sensible; for if those eminences were at the poles, it is obvious we should not perceive any tide at all; secondly, the equatorial diameter of the earth produced passes through the moon, which diameter is longer than any other, and consequently, there is greater disproportion between the distances of the zenith, centre, and nadir, from the centre of

gravity of the earth and moon, in this situation, than in : other: and thirdly, the water rising higher in the open se rushes to the shores with greater force, where being stopp it rises higher still; for it not only rises at the shores in p portion to the height it rises to the open seas, but also cording to the velocity with which it flows from thence agai the shore. The spring tides which happen a little before vernal and after the autumnal equinox, are the greates all, because the sun is nearer the earth in winter than in summer.

229. **When the moon is in the northern hemisphe it produces a greater tide while it is in the merid above the horizon, than when it is in the meridian l low it; when in the southern hemisphere, the rever**

Obs. For the like reason, when the moon is in the sou ern signs, the greatest tides on the other side of the equa will be when it is below our horizon, and the least tides wl it is above it.

2. What hath been said of the tides, must be underst upon supposition, that the globe of the earth is entirely cov ed with water to a considerable depth; but continents wh stop the tide, streights between them, islands, and the sl lowness of the sea in some places, which are all impedim to the course of the water, cause many exceptions which only be explained from particular observations on the nat of tides at different places.

OF MARS ♂.

230. The diameter of Mars is 5400 miles.—It : volves about its axis in 24h. 40′.

Sidereal revolution { 686d. 23h. 30′. 35″ 6. or 1 year, 321 days.

Longitude, Jan. 1, 1815 . .	7s. 28° 1
Annual motion . . .	6 11 17
Aphelion	5 2 35
Secular motion of aphelion . .	1 51
Node	1 18 6
Secular motion of node . .	46
Inclination of orbit . . .	1
Greatest equation . . .	10 40
Relative excentricity . .	14183

Excentricity in miles - -	13,254,852
Relative mean distance from the sun	152,369.27
Mean distance in miles - -	145,014,148

Obs. 1. When Mars is in opposition to the sun, it is nearest to the earth, and its diameter consequently appears the greatest. It never shines with a bright light, but has a red appearance, whence it is concluded it has a dense atmosphere. It appears with different phases according to its position, though never horned, its face being always greater than a semi-circle.

The following particulars respecting Mars are given by Dr. Herschel, after long and accurate observations.

The axis of Mars is inclined to the ecliptic 59° 42′.

The node of the axis is in 17° 47′ of Pisces.

The obliquity of the ecliptic on the globe of Mars, is 28° 42′.

The point Aries on the martial ecliptic answers to our 19° 28′ of Sagittarius.

The figure of Mars is that of an oblate spheroid, whose equatorial diameter is to the polar one as 1355 to 1272, or as 16 to 15 nearly.

The equatorial diameter of Mars, reduced to the mean distance of the earth from the sun, 9″ 8‴.

And that planet has a considerable, but moderate atmosphere, so that its inhabitants, probably, enjoy a situation, in many respects, similar to ours.

OF VESTA ⚶.

231. Diameter 1800 miles.

Distance from the sun -	224,145,000.
Sidereal revolution - -	4 years, 4 months.
Inclination of orbit - -	16°
Excentricity in miles - -	30,000,000
Ascending node - -	5s. 11° 6′

OF JUNO OR HARDING ⚵.

Diameter 1500 miles.

Distance from the sun - -	253,541,000
Sidereal revolution - - -	5 years.
Inclination of orbits - - -	21°
Excentricity in miles - - -	60,000,000

OF CERES OR PIAZZA ⚳.

233. Diameter 1700 miles.

Sidereal revolution 1680 days, or 4 years 266 days.

Distance from the sun - -	263,344,042		
Excentricity - - - -	21700		
Inclination of orbit - - -	10°	36′	
Ascending node - - -	25	21	6
Longitude, Jan. 1, 1801 -	25	17	19
Aphelion - - -	10s	26	9

OF PALLAS OR OLBERS ⚴.

234. Diameter 2000.

Sidereal revolution { 1682 days, or 4 years, 7 months, and 11 days.

Distance from the sun -	263,153,691.		
Excentricity - - -	24640		
Inclination - - -	34°	39′	
Ascending node - - -	5s.	22	28
Longitude, Jan. 1, 1804 -	9	29	53
Aphelion - - -	10	1	7
Annual motion - - -	2	18	11

Obs. These anomalous bodies, so unlike the other primary planets, Dr. Herschel has denominated Asteroids. Probably they are the fragments of some comet; or perhaps other similar bodies abound in the solar system, though they have hitherto from their smallness or darkness, escaped observation.

OF JUPITER ♃.

285. Diameter 94000 miles.

Diurnal rotation 9h. 56′.

Sidereal revolution 4332d. 14h. 27′ 10.8, or 11y. 315d.

Geo. longitude, Jan. 1, 1815	6s.	9°.	20′.	
Annual motion - .	0	0	20	34
Aphelion - - -	6	11	17	48
Secular motion of Aphelion -		1	34	33
Node - - -	3	8	31	14
Secular motion of node - -			59	30
Inclination of orbit - -		1	18	56

Greatest equation	- - -	5 31
Relative excentricity	- -	25013.3
Excentricity in miles	- - -	23375454
Mean distance in miles	-	495,990,976

Obs. 1. Jupiter is the largest of the planets, and has a bright appearance; but less so than Venus, on account of its much greater distance. Like Mars, it appears largest when in opposition to the sun; when it is to the west of the sun, it is a morning star, and when to the east of it an evening star. Its axis being nearly perpendicular to the plane of the orbit, there is but little diversity of seasons. It is surrounded by many faint substances, called belts, which are parallel to its equator; their numbers are variable; between them are frequently seen dark spots. Jupiter has four satellites.

2. Jupiter is surrounded by cloudy substances, subject to frequent changes in their situation and appearance, called his Belts. The Belts are sometimes of a regular form; sometimes interrupted and broken; and sometimes not at all to be seen.

OF SATURN ♄.

236. Saturn's diameter is 78000 miles.

Diurnal rotation 10h. 16′.

Sidereal revolution { 10759d. 1h. 51. 11.2 or 29y. 162d.

Geo. longitude, Jan. 1, 1815	-	10s.	0°.	32′.	
Annual motion	- - - -		12	13	19
Aphelion	- - -	8	29	15	11
Secular motion of aphelion	- -		1	50	7
Node	. - -	3	22	5	40
Secular motion of node	- -			55	30
Inclination of orbit	- -		2	29	50
Greatest equation	- - -		6	26	42
Relative excentricity	- - -				53640.42
Excentricity in miles	- -				50127670
Mean distance in miles	- -				907,956,130.

237. Saturn is a beautiful object for a good telescope, having SEVEN MOONS, A DOUBLE RING, and substances similar to the belts of Jupiter. Saturn's ring is a thin, broad, opaque circle, encompassing the planet without touching it; and is very similar to the horizon of a globe surrounding the globe: and as Saturn's axis is perpen-

dicular to its ring, if the globe be rectified for
it will aptly represent the planet and the rin

Obs. 1. The distance of the inner ring from Satur
miles, and its breadth 19024 miles: between the tw
space of 2927 miles; and the breadth of the outer r
miles. Saturn has an atmosphere extending to the
light of this planet is pale and feeble, on account
distance.

2. The latter discoveries of Dr. Herschel have
what was supposed to be a single broad flat ring
divided into two parts, lying exactly in the same
revolving about an axis perpendicular to that pla
32′ 15″.

OF HERSCHEL ♅.

238. The diameter of this planet is 3510
Sidereal revolution 30737d. or 83y. 321d.

Geo. longitude, Jan. 1, 1815.	-	8s. 4
Annual motion	- - - -	0 0
Aphelion	- - - - -	11 16
Secular motion of Aphelion	- -	1
Ascending node	- - -	2 12
Secular motion of node	- -	0
Inclination of orbit	- - -	0
Greatest equation	- - -	5
Relative excentricity	- -	
Excentricity in miles	- -	84
Relative mean distance from the sun		1
Mean distance in miles	- -	1,816,

Obs. 1. This planet was discovered by Dr. H
March 13, 1781. Its appearance is like that of a
tween the sixth and seventh magnitude, and the
scarcely be seen without a telescope. The Hersch
satellites. He modestly called it *Georgium Sidus.*

2. If the planets Mercury, Venus, the Earth, Ma
and Saturn, be in conjunction at any time; in the
280,000 years they will be very nearly in conjunc

	Revolutions.	*Se*
Mercury after making -	1162577 in	8838
Venus - - - - -	455122 —	8835
The Earth - - - -	280000 —	8835
Mars - - - -	148878 —	8835

	Revolutions.	Seconds.
Jupiter	23616 in	8835946544448
Saturn	9516 --	8835946558608

3. An easy distinction between a planet and a fixed star is this: the former shines with a steady light, but the latter is constantly twinkling. This twinkling or scintillation of a star is occasioned by the irregular progress of the light from such distant bodies to the eye.

OF THE SECONDARY PLANETS.

239. The secondary planets are those which move round some primary planet, as their centre, in the same manner as the primary planets move round the sun.

The earth is thus attended by one secondary planet, called the Moon; Jupiter by four, Saturn by seven, and Herschel by six.

240. The motion of a secondary planet in its orbit is not nearly so uniform as that of a primary; because though every secondary gravitates chiefly towards its primary as a centre, yet its motion is much disturbed by the unequal action or influence of the sun.

OF THE MOON ●.

241. Its diameter is 2180 miles.

It revolves about its axis in 29d. 12h. 44′.2″. 8283.

Mean distance from the earth .	236347 miles.
Mean excentricity . .	13035′
Greatest equation . .	6°. 18′. 32″.
Greatest inclination of orbit .	5 18
Least inclination of orbit .	5 0
Greatest diameter . .	33 24
Least diameter . .	29 22
Tropical revolution ..	27d. 7h. 43′. 4″.6795
Sidereal revolution .	27 7 43 11 5259
Synodic revolution . .	29 12 44 2 .8283
The excentricity .	13 700 miles.
Horizontal parallax .	53′ 46″ to 61′ 26″.
Sidereal revolution of the apogee . .	8y.312 11 11 39.4049

Sidereal revolution of the node - -	18y.223	7	13	17.744
Longitude, Jan. 1, 1815	5s. 26°.	13'.	53"	
Diurnal motion, in respect to the equinox - -		13	10	35.0278

New moon January, 1815, at 10d. 1h. 57'.

Def. 1. The *tropical revolution* signifies the complete revolution of 12 signs, performed round the earth, and is sometimes called a periodical month.

The *sidereal* signifies a completion of the motion to the same star, and is something longer than the tropical on account of the precession of the equinoxes.

The *synodic* revolution is the time from one conjunction with the sun, or one new moon to another, this exceeds the sidereal, and it will be found that in 29d. 12h. 44'.2".8283 that the moon will be again in conjunction with the sun, the earth being at the distance of 29°. 6' 20'.2 from the place of the former conjunction.

2. When the moon is at its greatest distance from the earth in its orbit, which is ecliptical, or at its higher apsis, it is said to be in its *Apogee;* when at its least distance, or lower apsis in its *Perigee.*

3. When the moon is in conjunction with the sun, it is *New Moon;* when in opposition, it is *Full Moon:* its conjunction and opposition are called by the common name of its *Syzygies.*

242. The moon at its conjunction, is invisible ; at its opposition, its whole disc is enlightened; at its quadratures, it is half enlightened ; between the conjunction and quadrature, it is horned; and between the quadrature and opposition, it is gibbous.

(*See Fig.* 69—*Frontispiece.*)

Illus. S is the sun, T the earth, ABC, &c. the moon in its orbit. One half of the moon is always enlightened by the sun. At A, the moon is between the earth and sun, it is then *new;* and is invisible as represented at *a:* at B the enlightened part *x z* is turned to the earth, and she appears horned as at *b ;* at C the half of the enlightened side is turned to the earth, and she appears a half moon as at *c;* at D the part *x z* is turned to the earth, and it appears as at *d* ; and at E the whole of the enlightened part of the moon is turned to the earth, and we have full moon as at *e.* As she passes through the rest of the orbit, she puts on the same phases as before, but in a contrary order

Obs. The earth must be a satellite to the moon, and subject to the same changes, but more than 13 times larger than the moon appears to us. At new moon to us, the earth appears full to her.

243. The moon always has nearly the same side towards the earth.

Obs. 1. Hence if the moon revolves about its axis, its periodical time must be equal to that of its revolution in its orbit round the earth. This is also found to be the case with the fifth satellite of Saturn as it regards the primary.

2. Though the year is of the same absolute length, both to the earth and moon, yet the number of days in each is very different; the former having 365 1-4 natural days, but the latter only about 12 7-19, every day and night in the moon being as long as 29 1-2 on the earth.

244. The moon appears to have two librations, one upon a line perpendicular to its axis, called its libration in latitude; the other upon its axis, called its libration in longitude.

Obs. This appears from observation; some small portions of the surface of the moon being visible in some parts, and invisible in other parts, of its orbit; that is, in consequence of her libration in latitude we sometimes see one pole and sometimes the other. And by this libration in longitude, more of the western limb is sometimes seen, and at others more of the eastern. The inclination of her axis to her orbit is 60° 49′.

245. The nearer the moon is to its *syzygies*,* the greater is its velocity; and the nearer it is to its quadratures, the slower it moves.

246. When the earth is in its perihelion, the periodical time of the moon is the greatest; when the earth is in its aphelion, the periodical time of the moon is the least.

Obs. Since all the irregularities of the moon's motion proceed from the action of the sun, it follows, that where the action of the sun is greatest, the irregularities arising from it will be greatest too. But the nearer the earth is to the sun, the greater will be the action of the sun upon the moon; and the more the moon tends towards the sun, the less will it tend towards the

* The line joining the centres of the sun, earth, and moon, at the *new and full* moon, is called the line of syzygies.

earth. When, therefore, the earth is at the perihelion, consequently at its least distance from the sun, the action the sun upon the moon will be greatest, and destroy mor its tendency towards the earth than at any other distan Therefore, when the earth is at the perihelion, the moon describe a larger orbit about the earth, than when the ea is at any other distance from the sun, and, consequently, periodical time will then be the longest. But the earth i its perihelion in the winter, and consequently, then the m will describe the outermost circle about the earth, and periodical time will be the longest; which agrees with servation. For the same reason, when the earth is at aphelion, the tendency of the moon towards the earth will the greatest, and, consequently, her periodical time the le And in this case, which will be in the summer, it will descr the innermost circle about the earth.

247. The excentricity of the moon's orbit is va ed in every revolution of the moon, and is great when the moon is in syzygy, and least when it is quadrature: and the orbit is most of all excentri when the line of the *apsis* is in the syzygies, and le of all excentrical when this line is in the quadratur

Obs. 1. And if we compare several revolutions of the m together, we shall find, that when the line of the *apsis* i the syzygies, the excentricity will be the greatest of all, cause in that situation, the difference between the tende which the moon has to the earth in one of the *apsis*, and t which it has in the opposite one, is the greatest of all; whe as, when the line of the *apsis* is in the quadrature, this dif ence is the least, and therefore the lunar excentricity will so too.

When the gravity of the moon towards the earth decre too fast, the excentricity of her orbit will increase, and w her gravity towards the earth increases too fast, the exc tricity of her orbit will decrease: and the orbit itself will proach nearer to a circle.

3. All the irregularities of the moon are greater when earth is in its perihelion, than when it is in its aphelion, cause the effect of the sun's action, whereby they are pro ced, is inversely as the square of its distance from the ea They are also greater when the moon is in conjunction w the sun, than in opposition, for the same reason; for the ea and moon, taken together, are nearer the sun in the fir situation of the moon, than they are in the latter.

248. The moon is a dark, opaque globe, and its surface is irregular.

Obs. 1. The face of the moon, as seen through a telescope, appears diversified with hills and valleys. This is proved by viewing her at any other time than when she is full; for then there is no regular line bounding light and darkness; but the edge or border of the moon appears jagged; and even in the dark part near the borders of the lucid surface there are seen some small spaces enlightened by the sun's beams. Besides, it is moreover evident, that the spots in the moon taken for mountains and valleys, are really such from their shadows. For in all situations of the moon, the elevated parts are constantly found to cast a triangular shadow in a direction from the sun, and the cavities are always dark on the side next to the sun, and illuminated on the opposite side.

2. By the observations made by Dr. Herschel in November, 1779, and the four following months, we learn, that the altitude of the lunar mountains has been very much exaggerated. His observations were made with great caution, by means of a Newtonian reflector, 6 feet 8 inches long, and with a magnifying power of 222 times, determined by experiment; and the method which he made use of to ascertain the altitude of those mountains, which during that time, he had an opportunity of examining, seems liable to no objection. The rock situated near *Lacus niger*, was found to be about one mile in height, but none of the other mountains, which he measured, proved to be more than half of that altitude; and Dr. Herschel concludes that, with a very few exceptions, the generality of the lunar mountains do not exceed half a mile in their perpendicular elevation.

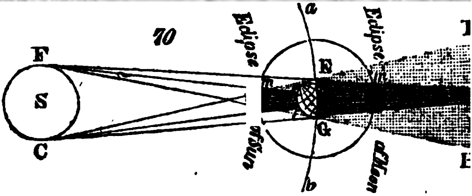
3. To Dr. Herschel we are also indebted for an account of several burning volcanoes, which he saw at different times in the moon. In the 77th vol. of the Phil. Trans. he says, "I perceive three volcanoes in different places of the dark part of the new moon. Two of them are nearly extinct; or, otherwise in a state of going to break out. The third showed an actual eruption of fire, or of luminous matter." On the next night, Dr. Herschel saw the volcano burn with greater violence than on the preceding evening. He considered the eruption as resembling a small piece of burning charcoal when it is covered by a thin coat of white ashes, which frequently adheres to it, when it has been some time ignited, and it had a degree of brightness, about as strong as that with which such a coal would be seen to glow in faint day-light.

249. An *Eclipse of the Moon* happens when th
passing between the sun and moon, casts its s
on the moon, and of course the moon can
eclipsed at the full, or in opposition, and whe
full, it is in or near one of its nodes.

Obs. 1. For it is only when the moon is in opposit
it can come within the shadow of the earth, which
ways be on that side of the earth which is from the su

2. The earth being in the plane of the ecliptic, th
of its shadow is always in that plane; if therefore th
be in its nodes, that is, in the plane of the ecliptic,
dow of the earth will fall upon it: also, since this sh
of considerable breadth, it is partly above and partl
the plane of the ecliptic; if therefore the moon in op
be so near one of its nodes, that its latitude is less t
the breadth of the shadow, it will be eclipsed. But
the plane of the moon's orbit makes an angle of more
degrees with the plane of the ecliptic, it will frequent
too much latitude at its opposition to come within the
of the earth.

70



3. Let S represent the sun, fig. 70, *m* the moon
the earth and the sun, *a* E G *b* a portion of the ear
bit, *e* and *f* two places on the surface of the eart
dark part of the moon's shadow is called the *umb*
the light part the *penumbra;* now it is evident that if
tator be situated in that part of the earth where the
falls, that is, between *e* and *f*, there will be a total e
the sun at that place; at *e* and *f*, in the penumbr
will be a *partial* eclipse; and beyond the penumbr
will be no eclipse. As the earth is not always at th
distance from the moon, if an eclipse should happen w
earth is so far from the moon that the lines F *e* and C
each other before they come to the earth, a spectato
ed on the earth, in a direct line between the centre
sun and moon, would see a ring of light round the da

of the moon, called an *annular* eclipse; when this happens there can be no total eclipse any where, because the moon's umbra does not reach the earth. People situated in the penumbra will perceive a partial eclipse. According to M. de Sejour, an eclipse can never be annular longer than 12 min. 24 sec. nor total longer than 7 min. 58 sec. The duration of an eclipse of the sun can never exceed two hours. *Keith*, 168.

250. The sun being larger than the earth, the shadow of the earth is a cone, the base of which is on the surface of the earth, and the moon is eclipsed by a section of the earth's shadow.

Obs. If the earth were larger than, or equal to, the sun, it is manifest that its shadow would either perpetually enlarge, or be always of the same dimensions; but in this case the superior planets would sometimes come within it, and be eclipsed, which never happens. Therefore the sun is larger than the earth, and produces a shadow from the earth of a conical form, which does not extend to the orbit of Mars.

251. An eclipse of the moon is *partial*, when only a part of its disc is within the shadow of the earth; it is *total*, when all its disc is within the shadow; and it is *central*, when the earth's shadow falls upon the centre of the moon's disc.

Obs. 1. Let S, represent the sun, fig. 70, EG the earth, and *m* the moon in the earth's umbra, having the earth between her and the sun; DEP and HGP the penumbra. Now, the nearer any part of the penumbra is to the umbra, the less light it receives from the sun, as is evident from the figure; and as the moon enters the penumbra before she enters the umbra, she gradually loses her light and appears less brilliant.

2. The duration of an eclipse of the moon, from her first touching the earth's penumbra to her leaving it, cannot exceed five hours and a half. The moon cannot continue in the earth's umbra longer than three hours and three quarters, in any eclipse, neither can she be totally eclipsed for a longer period than one hour and three quarters. As the moon is actually deprived of her light during an eclipse, every inhabitant upon the face of the earth, who can see the moon will see the eclipse. *Keith*, 169.

252. An *Eclipse of the Sun* happens when the moon, passing between the sun and the earth, intercepts the sun's light, and the sun can only be eclipsed at the new

moon, or when the moon, at its conjunction, is ii near one of its nodes.

Obs. For unless the moon is in or near one of its nod(cannot appear in or near the same plane with the sun : w out which, it cannot appear to us to pass over the disc o sun. At every other part of its orbit, it will have so m northern or southern latitude, as to appear either abov below the sun. If the moon be *in* one of its nodes havin altitude, it will cover the whole disc of the sun, and pro(a *total eclipse*, except when its apparent diameter is less that of the sun : if it be *near* one of its nodes, having a s degree of latitude, it will only pass over a part of the s disc, or the eclipse will be partial.

253. In a total eclipse of the sun, the shadow the moon falls upon that part of the earth where eclipse is seen.

Obs. A spectator, placed any where in the centre, wil see any part of the sun, because the moon will intercep the rays of light which come to him directly from the s and it is manifest that, in this situation, the moon, bein opaque body, will cast its shadow upon that part of the e where the eclipse is total.

254. In a partial eclipse of the sun, a *penumbra* imperfect shadow of the moon, falls upon that pa the earth where the partial eclipse is seen.

255. If the moon, when new, is in one of its no(the eclipse of the sun will be central.

Obs. 1. For then the centres of the earth, sun, and m(being all in the plane of the ecliptic, the centre of the m will pass between the sun's centre and that of the earth.

2. The penumbra of the moon, in a central eclipse, not cover the whole disc of the earth. The semi-diamet(the moon's penumbra, being equal to the sum of the appa semi-diameters of the sun and moon, that is, about 23″. X 15′. 37″. or 32′. at the medium; its diameter is al 64′. whereas the diameter of the earth's disc is about 1 whence the penumbra cannot cover the whole disc.

3. The height of the shadow of the moon is about 60 1-2 se diameters of the earth. The semi-angles of the earth's s dow and the moon's shadow, being each equal to the sun's parent semi-diameter, the angles are equal to one another, these cones are similar. Therefore as the semi-diameter of base of the earth's shadow (that is, of the earth) is to the se

diameter of the base of the moon's shadow, (that is, of the moon,) so is the height of the earth's shadow to the height of the moon's shadow. Now the semi-diameter of the earth is to that of the moon nearly as 100 to 28, and the height of the earth's shadow is about 217 semi-diameters of the earth; whence the height of the moon's shadow is equal to about 60 1-2 semi-diameters of the earth; for 100 : 23 : : 217 60 1-4 nearly.

256. An eclipse of the sun is said to be *annular*, when at the time of the eclipse a ring of the sun appears round the edges of the moon; and a central eclipse of the sun will be an annular one, if the distance of the moon from the earth at the time of the eclipse be greater than its mean distance.

257. If the orbit of the earth and that of the moon were both in the same plane, there would be an eclipse of the sun at every new moon, and an eclipse of the moon at every full moon. But the orbit of the moon makes an angle of about five degrees and a quarter, with the plane of the orbit of the earth, and crosses it in two points called nodes.

Obs. 1. Astronomers have calculated that, if the moon be less than 17° 21′ from either node, at the time of new moon, the sun may be eclipsed; or if less than 11° 34′ from either node, at the full moon, the moon may be eclipsed; at all other times there can be no eclipse, for the shadow of the moon will fall either above or below the earth at the time of new moon; and the shadow of the earth will fall either above or below the moon, at the time of full moon.

2. To illustrate this, suppose the right hand part of the moon's orbit, fig. 70, to be elevated above the plane of the paper or earth's orbit, it is evident that the earth's shadow, at full moon, would fall below the moon; the left hand part of the moon's orbit at the same time would be depressed below the plane of the paper, and the shadow of the moon, at the time of new moon, would fall below the earth. In this case, the moon's nodes would be between E and *a*, and between G and *b*, and there would be no eclipse, either at the full or new moon; but, if the part of the moon's orbit between G and *b* be elevated above the plane of the paper, or earth's orbit, the part between E and *a* will be depressed, the line of the moon's

nodes will then pass through the centre of the earth and th of the moon, and an eclipse will ensue.

3. An eclipse of the sun begins on the western side of l disc, and ends on the eastern; and an eclipse of the moon b gins on the eastern side of her disc, and ends on the wester

4. The average number of eclipses in a year is *four*, tv of the sun, and two of the moon; and, as the sun and mo are as long below the horizon of any *particular place* as th are above it, the average number of visible eclipses in a ye is two, one of the sun and one of the moon. *Keith.*

258. When the moon is near the first of Aries, a is moving towards the tropic of Cancer, the time its rising will vary but little for several days toget er, and produce the phenomena of *a Harvest moon*.

Obs. 1. If the moon were to move in the equator, its moti in its orbit, by which it describes a revolution, in respect the sun, 29 days, 12 hours, would carry it every day ea ward from the sun about 22° 11′, whence, its time of risi would vary daily about 50 minutes. But because the moo orbit is oblique to the equator, nearly coinciding with t ecliptic, different parts of it make different angles with t horizon, as they rise or set; those parts which rise with t smallest angles, setting with the greatest, and the rever Now the less this angle is, the greater portion of the orbit ses in the same time. Consequently, when the moon is those parts which rise or set with the smallest angles, it ri or sets with the least difference of time, and the reverse. B in northern latitudes, the smallest angle of the ecliptic a horizon is made when Aries rises and Libra sets, and t greatest when Libra rises and Aries sets; and therefor when the moon rises in Aries, it rises with the least diffe ence of time. Now the moon is in conjunction in or ne Aries, when the sun is in or near Libra, that is in the autur nal months; when the moon rises in Aries, whilst the su is setting in Libra, the time of its rising is observed to va only two hours in 6 days in the latitude of London. This called the HARVEST MOON.

2. This circumstance takes place every month; but as does not happen at the time of full moon, there is no noti taken of it. When the moon's right ascension is equal to si signs, that is, when she is in or about the beginning of Libr there is the greatest difference of the times of rising, viz. abo an hour and 15 minutes. Those signs which rise with the lea angle set with the greatest, and the contrary; therefore, whe there is the least difference in the times of rising, there is th

greatest in setting, and vice versa. All this may be pleasingly exemplified by means of a celestial globe.

OF THE SATELLITES OF JUPITER.

259. The following table gives the periodical times and distances of Jupiter's satellites, and the angles under which their orbits are seen from the earth, at its mean distance from Jupiter.

Satellites.	*Days.*	*h. min.*	*Dis. in miles.*	*Angles of orbit.*	
1 —	1	18 26.6 —	266.000 —	3′	55″
2 —	3	18 17.9 —	423.000 —	6	14
3 —	7	3 59.6 —	676.000 —	9	58
4 —	16	18 5.1 —	1.189.000 —	17	30

Obs. The third satellite is the largest of all; the first and fourth are nearly of the same size; the second is the smallest.

260. These satellites of Jupiter are of great use in astronomy. (1) In determining the distance of Jupiter from the earth. (2) They afford a method of demonstrating that the motion of light is progressive. And (3) from the eclipses of the satellites of Jupiter, we ascertain the longitude of different places.

261. OF THE SATELLITES OF SATURN.

Satellites.	Periodical terms.				Distance in miles.
1 —	1 day.	8h.	53′	8″ —	135.000
2 —	—	22	37	22 —	107.000
3 —	1	21	18	27 —	170.000
4 —	2	17	41	22 —	217.000
5 —	4	12	25	12 —	303.000
6 —	15	22	41	13 —	704.000
7 —	79	7	48	— —	2.050.000

Obs. The 1st and 2d satellites were discovered by Dr. Herschel, in the years 1787 and 1788. To prevent mistakes he called them the 6th and 7th, though nearer to the planet than the other five. Dr. Herschel observes, that Saturn has probably a considerable atmosphere. It turns on an axis perpendicular to the ring, in 10h. 16′ 0.44″ and is flattened at the poles, so that the equatorial diameter is to the polar as 11 to 10.

OF THE SATELLITES OF HERSCHEL.

262. Dr. Herschel has at different times, discovered six satellites belonging to his new planet.

Satellites.	When discovered.		Periodical Ti
1 —	Jan. 18,	1790 —	5d. 21h. 35′.
2 —	Jan. 11,	1787 —	8 17 1 1
3 —	Mar. 26,	1794 —	10 23 4
4 —	Jan. 11,	1787 —	13 11 5
5 —	Feb. 9,	1790 —	38 1 49
6 —	Feb. 28,	1794 —	107 16 40

263. A ray of light is about eight minutes in ing from the sun to the earth.

Obs. From comparing the times of the apparent en and emersion of Jupiter's satellites, with tables calculat the mean distances of the earth from the satellite, the emersion at the least distance of the planets is found to h about 8 minutes sooner, and at the greatest distance al minutes later, than by the tables: consequently, the light is about 16 minutes in passing through the earth's or 8 minutes in coming from the sun to the earth. T ameter of the earth's orbit being 194,000,000 miles, the ve of light will be 194,000,000

————=202,088 miles in a second of
16–|–60

OF COMETS.

264. Comets are opaque and solid bodies. A c at a given distance from the earth, shines bri when it is on the same side of the earth as the than when it is on the contrary side; from whe appears that it owes its brightness to the sun.

Obs. 1. Of all the comets, the periods of only thre known with any degree of certainty. The first of these ets appeared in the years 1531, 1607, and 1782; and is e: ed to appear every 75th year. The second of them a ed in 1532 and 1661, and was expected to return in 178 every 129th year afterwards. The third, having last a ed in 1680, and its period being no less than 575 year not return until the year 2225. This comet, at its gr distance, is about 11,200,000,000 of miles from the sun its least distance from the sun's centre, which is 49,000 is within less than a third part of the sun's semi-diamete his surface. In that part of its orbit which is nearest t it moves at the rate of 880,000 miles an hour.

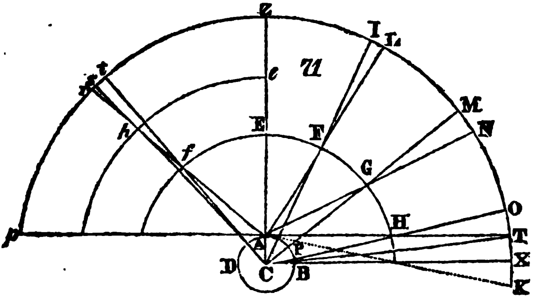
2. The Chinese astronomical books record the appearance of 2 or 300 comets.

3. The tail of the comet of 1680 was at least 100 millions of miles long; and that of 1812 was 30 millions of miles. Sir Richard Philips published in the Monthly Magazine the opinion that this wonderful appendage of comets, is occasioned by the refraction, and consequent condensation of the sun's light through the dense atmosphere of the comet: hence the tail is always in an exact right line opposite to the sun: and hence on the principle of a convex lens, the tail lengthens as it approaches the sun, and shortens as it departs.

OF THE PARALLAXES, DISTANCES, AND MAGNITUDES OF THE HEAVENLY BODIES.

265. The *Parallax* of the heavenly bodies, is the change of their apparent situation with respect to each other, as the spectator views them from different stations on the earth, or parts of the earth's orbit.

266. The *Diurnal Parallax* is the distance between the apparent place of a heavenly body, as viewed from the *surface* of the earth, and its apparent place, as viewed from the *centre* of the earth.



Obs. 1. Let DAB in fig. 71, be the earth, C its centre, A the station of a spectator on the surface of the earth; and F, G, H, different places of the moon, or any other heavenly body; TO, NM, LI, are its different parallaxes, and THO, or AHC; MGN, or AHC, &c. angles of parallax.

2. If a spectator in his first station at A, fig. 71 sees a et at G, its apparent place in the heavens will be N; if by the diurnal rotation of the earth, he comes into the s P, the planet will appear at M, which is the place in it would have appeared if viewed from C the centre: in all cases, the parallax which arises from the diurn tion, is the same which would arise from a change of s from the surface to the centre; for, in either cas change of the spectator's line of view is the same.] appears the propriety of the above definition of the *d parallax.*

267. The parallax of any planet is always pr tional to the angle which a semi-diameter of the (drawn from the station of the spectator upon the st to the centre, would subtend, if viewed from the p

Obs. 1. If the planet be at H, fig. 71, and the spectato AHT will be his line of view; on changing the station spectator from A to C, the line of view will become (whence TO will be the parallax. But TO subtends proportional to THO, or AHC, the angle which the (semi-diameter would subtend, if viewed from the pla

2. The parallax of a planet depresses its apparent pla the parallactic arc. Thus, if the planet be viewed from 71, its apparent place is O; if from A, its apparent plac farther from Z the vertex, than O, by the parallactic a

3. When the altitude of a body is observed, it must l rected by parallax or refraction, adding the former, an tracting the latter, in order to get the true altitude, altitude above the rational horizon at the centre of the

268. The diurnal parallax of any planet, at a distance from the earth, is greatest when the pl in the horizon, and it decreases as the altitude planet increases.

Obs. 1. The parallax is proportional to the angle whi fig. 71, would subtend, if seen from the planet H: bi given line, viewed from the given distance of the | would continually diminish in its apparent magnitude, degree of obliquity at which it is viewed increases, tha the planet advances from H towards E; therefore, the lax is greatest in the horizon, and decreases as the approaches the vertex. The parallactic angle AGC than AHC, and AFC less than AGC.

2. The moon's mean parallax is 57′.11″.

3. At the same altitude of different planets, their diurnal parallaxes are inversely as their distances from the centre of the earth, because the angles subtended by the semi-diameter will be mostly as the distances.

269. To measure the distance of the moon from the earth.

Def. The moon's *horizontal parallax* is the angle which a semi-diameter of the earth would subtend, if viewed directly from the moon.

Illus. Let H be the moon in the horizon observed by a spectator at A, fig. 71, and C the centre of the earth. In the triangle AHC, let the angle AHC, the moon's horizontal parallax, be found. The angle HAC is a right angle, and AC, the semi-diameter of the earth, is known to be 3985 miles.—Hence, AC the sine of AHC, 57′. 11″. is to 3985, as AH, taken as a radius, to the number of miles in HC, the moon's distance from the earth. The moon's mean distance is thus found to be 240,000 English miles.

Obs. According to M. de la Lande, the horizontal semi-diameter of the moon, is to its horizontal parallax for the mean radius of the earth as 15′. is to 54′. 57″. 4 or very nearly as 3 to 11 : hence, the semi-diameter of the moon is 3-11ths of the radius of the earth. And as the magnitudes of spherical bodies are as the cubes of their radii, the magnitude of the moon is to that of the earth as 3^3 to 11^3, that is, as 1 : 49.

270. To determine the *relative* distances of the inferior planets from the sun.

Illus. If the elongation of Venus, or the greatest angle of Venus' distance, be found by observation; then, as a radius is to the sine of the angle, so is the distance of the earth to the distance of Mercury. If the sun's distance from the earth be supposed to be divided into 1000 equal parts, then the distance of Mercury, will in this manner be found to be 387, and that of Venus 723.

171. To determine the *relative* distances of the superior planets from the sun.

Obs. If the angle apparently performed by a superior planet, while the earth is moving from one end to the other of its axis, be determined by observation, then half that angle is the angle formed by the distance of the earth from the sun seen from the planet. Hence there is given that angle, the right angle at the sun, and the complement to 180°, *i.e.* three angles and the base 1000, the earth's distance, to find the perpendicular in a right

angled triangle. If the mean distance of the earth sun be called 1000, that of Mars will be thus found t that of Jupiter 5201, and that of Saturn 9538.

272. To find the parallax of the sun by th of Venus.

Obs. 1. This is one of the most important proble to astronomy; because when the precise angle is 1 der which the semi-diameter of the earth is seen at triangle is given of which one angle is 90° at the ea tre, the other the parallax at the sun, (being the an which the earth's semi-diameter is seen,) and the complement of the same to 90°, and the base is semi-diameter known by measurement.

2. Venus would be seen like a dark spot on the sun, as often as she passes in her orbit between th the earth, but that the plane of her orbit does no with the plane of the earth's orbit, and she passes in the eye of a spectator at the earth, above or belo except only when he happens to be in or near her no time of the conjunction. This, however, happens b the nearest transits to our time being in 1639, 1' and 1814.

3. Nothing is more easy to be understood than th tion of the phenomenon of a transit to ascertain the the Earth from Venus and the Sun. All that is wa angle presented at Venus, by any known portion of surface, and this is determined, by observing the at which Venus enters or leaves the sun's face or two places, and then converting the difference of tin ing for geographical difference,) into degrees, mi seconds, which is of course, the parallax of Venus the general principle; but the details of the calcu rendered complex by the various distances of obs their opportunities of observing, and by the compo of the Earth and Venus, in the intervals of observa these points are, however, susceptible of unerring c

4. The parallax of Venus being thus determined parallax is easily determined by the proportions in article 278, and it appears to be 8 2-3 seconds, i. e diameter of the earth equal to 3985 miles subtends an angle of 8.65 seconds, and by trigonometrical c the perpendicular of the triangle, or the line joinin and the earth's centre, is 95,173,000 miles, thus by we have 5.621914 (the sine of 8″. 65.) : 10.000000 :

(log. of 3985:) 95,173,000 miles. But some astronomers make the parallax somewhat more, and make it but 93 or 94 millions, while others make it less, or 96 millions.

273. To measure the distance of any planet from the sun.

Illus. Because the real distances of the planets from the sun are as their proportional distances; as the proportional distance of the earth from the sun is to the proportional distance of any other planet from the sun, so is the real distance of the earth from the sun in miles, to the real distance of any planet from the sun in miles.

Hence are found the distances of the planets from the sun in English miles. Mercury, 36,841,468; Venus, 68,891,486; Mars, 145,014,148; Jupiter, 494,990,976; Saturn, 907,956,-139; and the Herschel 1800,000,000, all agreeable to the fact of the sun's parallax being 8 2-3 seconds.

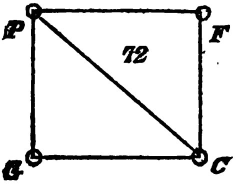
274. To find the periodical time of a planet.

Obs. Because the squares of the periodical times of the planets were found by Kepler to be as the cubes of their distances, the periodical times of any two planets being known, and the comparative or real distance of one of them from the sun being given, the distance of the other may from this proportion be found.

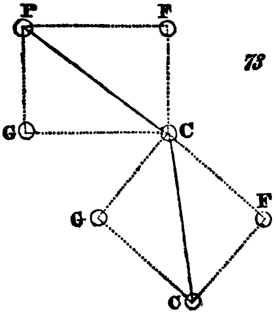
CAUSES OF THE PLANETARY MOTIONS.

275. According to the Greeks, and the demonstrations of Newton, the planets are retained in their orbits by *gravitation*, which draws or impels them towards the centre of motion, and carried forward by a *projectile force*, which tend to carry them off at right angles to the other force, or in a tangent to their orbit.

Illus. 1. The motion of the primary planets is very simple and uniform, being compounded only of a projectile motion forwards in a straight line, which is a tangent to the orbit: and a gravitation towards the sun in the focus. The power which occasions the former is called a centrifugal force, and that which occasions the latter a centripetal one; and though gravitation is mutual between all the planets, being directly as the quantities of matter they contain, and inversely as the squares of their distances from each other; yet the motions of the planets are not much affected by it; for their quantities of matter are but very small when compared with that of the sun, and therefore its attraction, or their gravitation towards it, nearly destroys that of the planets one towards another.



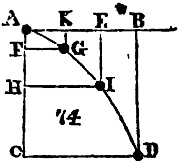
Illus. 2. Suppose P, fig planet at rest, acted up force which tends to car wards G, which force is towards a centre, and ca *gravitating force;* but at t instant another force, ac right angles to the former, carry it towards F; the tw will of course, by the mechanical forces, carry it from P to C, in the diag square. If then the distances FP and PG are suppos infinitely small, or to represent the powers acting in th est conceivable portion of time, then the diagonal PC conceived to be an infinitely small portion of a circle, or of a circle so small that it coincides with a circle.



3. If then the actio same forces be renew in the directional CG the centre, and from right angles, the plane turned into the diagc forming another small chord, or increment of and the repetition of t pulses continued with ing, will, of necessit the planet round the body, in a circular orl

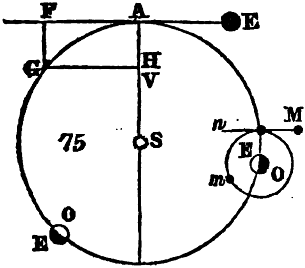
Obs. 1. The cause tation or of projectile not affected to be expl the Newtonian philosophy; it is simply assumed, t forces act according to certain laws, let their causes they may; and it is certainly more safe to treat of eff of causes, though to investigate the *latter* is the proj ness of philosophy.

276. If a body by an uniform motion, descr side of a parallelogram, in the same time that it describe the adjacent side by an accelerated for body, by the joint action of these forces, wo scribe a curve terminating in the opposite the parallelogram.



Let A B C D, fig. 74, be a parallelogram, and suppose the body A to be carried through A B by an uniform force, in the same time that it would be carried through AC by an accelerated force, then by the joint action of these forces, the body would describe a curve A G I D. For by the preceding illustration, if the spaces AE, EK, and KB, be proportioned to each other, the spaces AF, FH, and HC, will be in the same proportion, and the line AGID will be a straight line when the body is acted upon by uniform forces; but in this example, the force in the direction AB being uniform, would cause the body to move over equal spaces, AB, EK, and KB, in equal portions of time; while the accelerative force in the direction AC, would cause the body to describe spaces A F, F H, and H C, increasing in magnitude in equal successive portions of time; hence the parallelograms AEGF, AKIH, &c. are not about the same diagonal, therefore AGID is not a straight line, but a curve.

277. The curvilinear motions of all the planets, arise from the uniform projectile motion of bodies in straight lines, and the universal power called attraction, which draws them off from these lines.

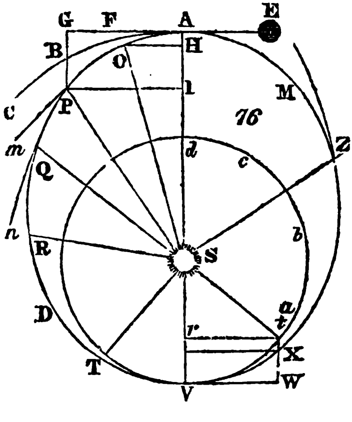


Illus. If the body E.fig.75, be projected along the line EAF, where it meets with no resistance, and is not drawn aside by any other force, it will (by the laws of motion) go on for ever in the same direction, and with the same velocity. For, the force which moves it from E to A in a given time, will carry it from A to F in a successive and equal portion of time, and so on; there being nothing either to obstruct or alter its motion. But if when the projectile force has carried the body to A, another body, as S, begins to attract it, with a power duly adjusted and perpendicular to its motion at A, it will be drawn from the straight line EAF,

and revolve about S in the circle* AGOOA. When the bo
E arrives at O, or any other part of its orbit, if the small bo
M, within the sphere of E's attraction, be projected as in t
straight line *M n*, with a force perpendicular to the attracti
of E, it will go round the body E, in the orbit *m*, and acco
pany E in its whole course round the body S.—Here S m
represent the sun, E the earth, and M the moon.

2. If the earth at A be attracted toward the sun at S, so
to fall from A to H by the force of gravity alone, in the sa
time which the projectile force singly would have carried
from A to F; by the combined action of these forces it w
describe the curve A G; and if the velocity with which E
projected from A, be such as it would have acquired by fa
ing from A to V (the half of AS,) by the force of grav
alone, it will revolve round S in a circle.

278. If one body revolve round another (as t
earth round the sun,) so as to vary its distance fro
the centre of motion, the projectile and centripe
forces must each be variable, and the path of the r
volving body will differ from a circle.



Il. Fig. 76. If wh
a projectile force ca
E from A to F the su
attraction at S wo
bring it from A to
the gravitating pow
would be too great;
the projectile for
the planet, therefo
instead of proceedi
in the circle ABC
in the preceding p
blem) would descri
the curve AO, and a
proach nearer to t
sun; SO being less th
SA. Now, as the ce
tripetal force or gra
tating power, alw
increases as the squ
of the planet's dista

* If any body revolve round another in a circle, the revolv
body must be projected with a velocity, equal to that whic

from the sun diminishes, when the planet arrives at O, the centripetal force will be increased, which will likewise increase the velocity of the planet, and accelerate its motion from O to P; so as to cause it to describe the arches OP, PQ, QR, RD, DT, TV, successively increasing in magnitude, in equal portions of time.

The planet being thus accelerated, it gains such a centripetal force, or tendency to fly off at V, in the line of VW, as overcomes the sun's attraction; this centrifugal or projectile force being too great to allow the planet to approach nearer the sun than it is at V, or even to move round the sun in the circle *t a b c d*, &c. it flies off in the curve XZMA, with a velocity decreasing as gradually from V to A, as if it had returned through the arches VT, TD, DR, &c. to A, with the same velocity which it passed through these arches in its motion from A towards V. At A the planet will have acquired the same velocity as it had at first, and thus, by the varied centrifugal and centripetal forces, it will continue to move round S.

But if the action of gravity be too great for the projectile force at O, why does it not draw the planet to S? and if the projectile force at V be too great for the centripetal force, or gravity, at the same point, why does it not carry the planet farther and farther from the sun, till it is beyond his attraction?

First, If the projectile force at A were such as to carry the planet from A to G, double the distance, in the same time that it was carried from A to F, it would require four times as much gravity to retain it in its orbit, viz. it must fall through AI in the time that the projectile force would carry it from A to G, otherwise it would not describe the curve AOP. But an increase of gravity gives the planet an increase of velocity, and an increase of velocity increases the projectile force; therefore, the tendency of the planet to fly off from the curve in a tangent P*m*, is greater at P than at O, and greater at Q than at P, and so on; hence, while the gravitating power increases, the projectile power increases, so that the planet or comet cannot be drawn into the sun.

Secondly, The projectile force is the greatest at, or near the point V, and the gravitating power is likewise the greatest at that point. For if A S be double of V S, the centripetal force at V will be four times as great as at A, being as the square of

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would have acquired, by falling through half the radius of the circle towards the attracting body.

Emerson's Cent. Forces, Prob. ii.

the distance from the sun. If the projectile force at V be double of what it was at A, the space VW, which is the double of AF, will be described in the same time that AF was described, and the planet will be at X in that time. Now if the action of gravity had been an exact counterbalance for the projectile force during the time mentioned, the planet would have been at *t* instead of X, and it would describe the circle *t*, *a*, *b*, *c* &c.; but the projectile force being too powerful for the centripetal force, the planet recedes from the sun at S, and ascends in the curve, YZM, &c. Yet it cannot fly off in a tangent in its ascent, because its velocity is retarded, and consequently its projectile force is diminished, by the action of gravity. Thus when the planet arrives at Z, its tendency to fly off in a tangent Z *n*, is just as much retarded, by the action of gravity, as its motion was accelerated thereby at Q, therefore it must be retained in its orbit.

OF THE FIXED STARS.

279. Those luminous points or bodies which always appear in the heavens at the same distance from each other, are called *Fixed Stars;* because they do not appear to have any proper motion of their own.

Obs. 1. The fixed stars are luminous bodies. Because they appear as points of small magnitude, when viewed through a telescope, they must be at such immense distance, as to be invisible to the naked eye if they borrowed their light; as is the case with respect to the satellites of Jupiter and Saturn, although they appear of very distinguishable magnitude through a telescope. Besides, from the weakness of reflected light, there can be no doubt but that the fixed stars shine with their own light. They are easily known from the planets, by their twinkling.

2. The number of stars, visible at any one time to the naked eye, is about 1000: but Dr. Herschel, by his skilful improvements of the reflecting telescope, has discovered that the whole number is great beyond all conception. The comparative brightness of the stars is Sirius 100, Canopus .98, Centauri 96, Acherni .94.

3. The magnitudes of the fixed stars appear to be different from one another, which difference may arise either from a diversity in their real magnitudes, or distances; or from both these causes acting conjointly. The difference in the apparent magnitude of the stars is such as to admit of their being divided

into six clases, the largest being called stars of the first magnitude, and the least, which are visible to the naked eye, stars of the sixth magnitude. Stars only visible by the help of glasses, are called telescopic stars. Bode's catalogue contains 17,000 stars. Dr. Halley very justly remarks, that the stars must be infinite in number to maintain their equilibrium in space. And Dr. Herschel thinks he has seen stars 42,000 times as far off as Sirius. In one instance a cluster of 5000 stars, in a mass, were barely visible in the 40 foot telescope, and consequently must have been 11 trillions of miles off!

4. It must not be inferred that all the stars of each class appear exactly of the same magnitude: there being great latitude given in this respect; even those of the first magnitude appear almost all different in lustre and size. There are also other stars of intermediate magnitudes, which, as astronomers cannot refer to any one class, they, therefore, place them between two. *Procyon*, for instance, which PTOLEMY makes of the first magnitude, and *Tycho* of the second, FLAMSTEAD lays down as between the first and second. So that, instead of six magnitudes, we may say that there are almost as many orders of stars, as there are stars; such considerable varieties being observable in their magnitude, colour, and brightness.

5. To the bare eye the stars appear of some sensible magnitude, owing to the glare of light arising from the numberless reflections of the rays in coming to the eye; this leads us to imagine that stars are much larger than they would appear, if we saw them only by the few rays which come directly from them, so as to enter the eye without being intermixed with others. Examine a fixed star of the first magnitude through a long and narrow tube, which, though it takes in as much of the sky as would hold a thousand such stars, scarcely renders that one visible.

6. There seems but little reason to expect that the real magnitudes of the fixed stars will ever be discovered with certainty, we must, therefore, be contented with an approximation, deduced from their parallax, (if this should ever be ascertained,) and the quantity of light they afford us compared with the sun. To this purpose, Dr. HERSCHEL informs us, that with a magnifying power of 6450, and by means of his new micrometer, he found the apparent diameter of α Lyræ to be 0''.335, or the third of a second.

7. The ingenious observations of KEPLER upon the magnitudes and distance of the fixed stars, deserve to be introduced, as he has been followed in the conjecture by DR. HALLEY. He

observes that there can be only 13 points upon the surface of a sphere as far distant from each other as from the centre; and supposing the nearest fixed stars to be as far from each other as from the sun, he concludes there can be only 13 stars of the first magnitude. Hence at twice that distance from the sun, there may be placed four times as many, or 52: at three times that distance, nine times as many, or 117; and so on. These numbers will give pretty nearly the number of stars of the first, second, third, &c. magnitudes. Dr. Halley farther remarks, that if the number of stars be finite, and occupy only a part of space, the outward stars would be continually attracted to those within, and in time would unite into one. But if the number be infinite, and they occupy an in finite space, all the parts would be nearly in equilibrio, and, consequently, each fixed star being drawn in opposite directions would keep its place or move on till it had found an equilibrium.

280. The ancients, that they might the better distinguish the stars with regard to their situation in the heavens, divided them into several constellations, that is, masses of stars, each mass consisting of such as are near each other. And to distinguish these groups from one another, they gave them the names of such men or things as they fancied the space they took up in the heavens represented.

Obs. 1. The following table contains the names of the constellations, and the number of stars observed in each by Flamstead.

		Flamstead.
Ursa minor	The Little Bear	24
Ursa major	The Great Bear	87
Draco	The Dragon	80
Cepheus	Cepheus	35
Bootes	Bootes	54
Corona Borealis	The Northern Crown	21
Hercules	Hercules kneeling	113
Lyra	The Harp	21
Cygnus	The Swan	81
Cassiopea	The Lady in her chair	55
Perseus	Perseus	59
Auriga	The Waggoner	66
Serpentarius	Serpentarius	74
Serpens	The Serpent	64

itta	The Arrow	18
ila	The Eagle	71
inous	Antinous	
phinus	The Dolphin	18
ulus	The Horse's Head	10
asus	The Flying Horse	89
romeda	Andromeda	66
angulum	The Triangle	16
es	The Ram	66
irus	The Bull	141
nini	The Twins	85
cer	The Crab	83
	The Lion	95
na Berenices	Berenice's Hair	43
go	The Virgin	110
ra	The Scales	51
rpius	The Scorpion	44
ittarius	The Archer	69
ricornus	The Goat	51
iarius	The Water-Bearer	108
ces	The Fishes	113
us	The Whale	97
on	Orion	78
danus	Eridanus	84
ous	The Hare	19
is major	The Great Dog	31
is minor	The Little Dog	14
o Navis	The Ship	64
lra	The Hydra	60
iter	The Cup	31
vus	The Crow	9
itaurus	The Centaur	12
pus	The Wolf	24
	The Altar	9
ona Australis	The Southern Crown	12
ces Australis	The Southern Fish	24
umbia Noachi	Noah's Dove	10
bur Carolinum	The Royal Oak	12
us	The Crane	13
enix	The Phœnix	13
us	The Indian	12
ro	The Peacock	14
ls	The Bird of Paradise	11

		Flamstead.
Apsis - - - -	The Bee or Fly - -	4
Chamæleon - - -	The Cameleon - -	10
Triungulum Australis -	The South Triangle -	5
Piscis Volans - -	The Flying Fish -	8
Dorado - - - -	The Sword Fish - -	6
Toucan - - -	The American Goose -	9
Hydrus - - - -	The Water Snake - -	10
Lynx - - - -	The Lynx - - -	44
Leo minor - - -	The Little Lion - -	53
Asterion & Clara - -	The Greyhound -	25
Cerbereus - - -	Cerberus - -	
Vulpecula & Anser -	The Fox and Goose -	35
Scutem Sobieski - -	Sobieski's Shield - -	
Lacreta - - -	The Lizard - -	16
Camelopardalus - -	The Cameleopard -	58
Monoceros - - -	The Unicorn - -	31
Sextans - - -	The Sextant - - -	41

2. Stars not included in any constellation are called *unformed* stars. Besides the names of the constellations, the ancient Greeks gave particular names to some single stars, or small collections of stars: thus the cluster of small stars in the neck of the bull, was called the *Pleiades*; five stars in the bull's face, the *Hyades*; a bright star in the breast of *Leo*, the *Lion's Heart*; and a large star between the knees of *Bootes*, *Arcturus*.

3 Greek letters have been added by Bayer to stars in the several constellations of his catalogue (α being affixed to the largest star) by means of which any star may be easily found.

4. Twelve of these constellations lie upon the ecliptic, including a space about fifteen degrees broad, called the *Zodiac*, within which all the planets move. The constellation Aries, about 200 years ago, lay in the first sign of the ecliptic; but on account of the precession of the equinoxes, it now lies in the second. In the foregoing table *Antinous* was made out of the unformed stars near *Aquila*: and *Como Berenices* out of the unformed stars near the *Lion's* tail. They are both mentioned by Ptolemy, but as unformed stars. The constellations as far as the triangle, with *Coma Berenices*, are *northern*; those after *Pisces*, are *southern*.

5. The luminous part of the heavens, called the *Milky Way*, consists of fixed stars too small to be seen by the naked eye. In a paper on the constructions of the heavens, Dr. Herschel says it is very probable, that the great stratum called the milky way, is that in which the sun is placed, though per-

t in the centre of its thickness, but not far from the place some smaller stratum branches from it. Such a suppo- rill satisfactorily, and with great simplicity, account for phenomena of the milky way, which, according to this esis, is no other than the appearance of the projection of rs contained in this stratum, and its secondary branch.

ı another paper on the same subject, he says,—We will treat to our own retired station in one of the planets at- ; a star in the great combination with numberless others; order to investigate what will be the appearances from ontracted situation, let us begin with the naked eye. ırs of the first magnitude, being, in all probability, the t, will furnish us with a step to begin our scale; setting erefore, with the distance of Sirius or Arcturus, for in- as unity, we will at present suppose, that those of the magnitude are at double, and those of the third at tre- e distance, and so forth. Taking it then for granted, star of the seventh magnitude is about seven times as far ıs as one of the first, it follows that an observer, who is ed in a globular cluster of stars, and not far from the , will never be able, with the naked eye, to see the end for since, according to the above estimations, he can xtend his view about seven times the distance of Sirius, ıot be expected that his eyes should reach the borders of ter, which has, perhaps, not less than fifty stars in depth where around him. The whole universe, therefore, to will be comprised in a set of constellations, richly orna- d with scattered stars of all sizes. Or if the united tness of a neighbouring cluster of stars should, in a re- able clear night, reach his sight, it will put on the ap- nce of a small, faint, nebulous cloud, not to be perceived ut the greatest attention. Allowing him the use of a ıon telescope, he begins to suspect that all the milkyness bright path which surrounds the sphere may be owing rs. By increasing his power of vision, he becomes cer- hat the milky way is, indeed, no other than a collection y small stars, and the nebulæ nothing but clusters of stars.

Dr. Herschel then solves a general problem for computing ength of the visual ray: that of the telescope, which he will reach to stars 497 times the distance of Sirius. Now s cannot be nearer than 100.000X190.000,000 miles,there- Dr. Herschel's telescope will at least reach to 100.000

X190.000.000.X497 miles. And Dr. Herschel s
the most crowded part of the milky way, he has
view that contained no less than 588 stars, and
continued for many minutes, so that in a quarter
he has seen 116,000 stars pass through the field
telescope of only 15′. aperture: and at another
minutes, he saw 258,000 stars pass through the
telescope. Every improvement in his telescope h
ed stars not seen before, so that there appears
their number, or to the extent of the universe.

8. There are spots in the heavens, called *Neb*
which consist of clusters of telescopic stars, othe
luminous spots of different forms. The most co
one of the mid way between the two stars on the
on's sword, marked θ by Bayer, and discovered
1656 by Huygens; it contains only seven stars, a
part is a bright spot upon a dark ground. To D
we are indebted for catalogues of 2000 nebulæ an
stars which he himself had discovered. Some of
round compact system, others are more irregula
forms, and some are long and narrow. The ap
luminous spaces in the heavens Sir Richard Phil
arise from light per se; but ascribes the luminosi
spaces to the multitude of planets, asteroids, s
cometary bodies, with which those spaces are fill

9. New stars sometimes appear, while other
Several stars, mentioned by the ancient astronor
now to be found: several are now visible to th
which are not mentioned in the ancient catalogue
stars have suddenly appeared, and again, after a
interval, vanished: also a change of place has be
in some stars. Dr. Herschel has observed th
nearly fifty stars, with reference to others in th
Castor he finds has a period of 342 years; Gamm
1200 years; Epsilon Bootes, of 1681 years; Del
of 375 years; Gamma Virginia of 708 years; a
ers: but the life of one man is evidently too sho
correct results, in regard to periods so disproport
narrow space of existence.

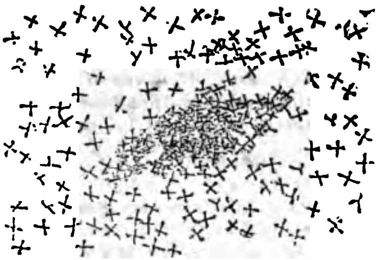
10. These motions of the stars among themsel
parent to observation, the doctrine of Dr. Hersch
astronomers is rendered probable, that the sun ha
orbit of its own among the fixed stars of the milk
rate of the earth's motion, carrying with it all the
as the planets themselves, carry with them their s

tellites in their own orbits. The rotation of the sun on its inclined axis, according to the theory of Sir Richard Philips, seems to indicate the action of a centrifugal force in the sun, and to render the notion, that the whole solar system is analogous to a primary and its satellites, exceedingly probable.

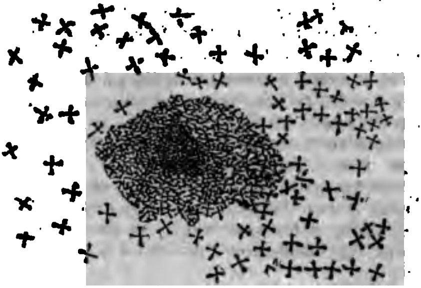
11. From an attentive examination of the stars with good telescopes, many which appear only single to the naked eye, are found to consist of numerous stars. α *Herculis*, is a double star, π *Bootis*, and Dr. Herschel, by his highly improved telescopes, has found about 700.

12. In February, 1814, Dr. Herschel, the prince of astronomers, read to the Royal Society, the results of thirty years' observations on Nebulæ, with the best telescopes ever possessed by man. He conceives that the stars form independent systems among themselves. He considers our sun as part of that shoal or system which we call the milky way, and that all the stars of the first, second, and third magnitude, belong to that vast cluster. The stars, he remarks, are not spread in equal portions over the horizon, but are found in patches, each containing many thousands, and many more than the eye can separate from the mass. These he calls clusters; and he conceives they have a constant disposition to unite more closely, by a power which he calls the clustering power; doubtless the same power which is described in the observation to article 276. He gives an account of eighty of these clusters, some of the drawings of which are copied here.

The following figure represents a COMPRESSED CLUSTER of STARS, the centre part 8′ long 2′ broad.



The following figure represents another similar CLUS STARS.



The following figure represents a GLOBULAR CLUS in diameter, as seen with Herschel's 40 feet telescope.

281. The *Annual Pa* of a heavenly body, change of its apparent as it is viewed from the in its annual motion ; the angle which the dia of the earth's orbit subtend, if that diamete viewed from that body.

282. If the distance object be greater than 100,000 times the base angles at the stations will not sensibly differ from angles ; consequently, the lines drawn from th ject to the stations, are, physically speaking, pa and the parallax of an object, the distance of wl above 100,000 times greater than that between th stations of observation, is consequently insensibl

Obs. If the object be at a greater distance from eith tion than 100,000 times the base, the angle at one of the s being 90°, the angle at the other will be more than 8 57″. 9, the difference of which angle and 90° being so more than 2″, is too small to become sensible by obser

283. If the parallax of an object (observed with an instrument sufficiently exact to measure an angle of 2''.) be insensible, the distance of the object from either station cannot be *less* than 100,000 times the base, yet it may be greater in assignable ratio.

Obs. Lines drawn from any given points in a base, to an object, may be esteemed in practice, parallel, without any sensible error, if the distance of the object be more than 100,000 times the base. Rays, therefore, diverging from any point in the sun's disc upon the surface of the earth, may be esteemed parallel, if their distance from each other do not exceed about 970 miles at the earth's surface: because 970 is to the distance of the earth from the sun in a proportion of 1 to 100,000.

284. The fixed stars have no sensible annual parallax, because when the place of any star is observed by the best instruments, from opposite points or ends of the earth's orbit, its apparent place in the heavens remains the same, which could not be the case, if the angle of its parallax were so much as *two seconds.*

Obs. 1. Hence it appears that the fixed stars are so remote, that a diameter of the earth's orbit bears no proportion to their distance, or that a diameter of the earth's orbit, if viewed from one of the fixed stars, would appear as a point.

2. The distance of the stars must be greater than 100,000 times the base, from the extremities of which it is observed, that is, greater than 100,000 times the diameter of the orbit of the earth, or greater than 100,000×190,000,000, which is nineteen billions of miles as the least possible distance of the nearest fixed star.

3. The parallax of a fixed star, being not more than 2''. the sun, when viewed from that star, would appear under an angle less than $\frac{32' 6''}{200,000}$, or less than $\frac{1''}{100}$, and, therefore, could not be distinguished from a point.

4. Since bodies equal in magnitude and splendour to the sun, being placed at the distance of the fixed stars, would appear to us as the fixed stars now do, it may be supposed probable, that the fixed stars are bodies similar to the sun, which is the centre to the solar system. This being the case, the reason will appear, why a fixed star, when viewed through a teles *magnifying 200 times*, appears no other than a point. T *apparent diameter* of the star being less than 1-100 p

second, when magnified 200 times, will subtend an angle le that 2''. at the eye of the spectator, observing it in the tel scope.

5. The parallax of the fixed star, when viewed from t opposite parts of the earth's orbit, is here assumed 2''. but is probable that the parallax of the nearest star is much le and consequently the distance greater, in the same proporti as the parallax is less. Dr. Bradley thought that if the para lax of a fixed star had been one second, he should have be able to detect it. The diameter of the earth's orbit is, ther fore, but a point at the fixed stars. Nor is this wonderful, the immense distance of the stars themselves is but a poi compared with the *infinite* extension of space. Doubtless, t stars in the clusters seen by Herschel, are as distant from ea other, as the fixed stars of our cluster of the milky way, a found to be from each other, yet those clusters seen from th earth are but points! No considerations can be more wonde ful or sublime!

QUESTIONS ON ASTRONOMY.

What is *astronomy?*

What constitutes the *solar system?*

What are the names of the *primary planets* composing t solar system?

What are the names of the *asteroids?*

What is the number of the secondary planets, and to wh primary planets do they belong?

Explain the solar system.

What was the system of Ptolemy?

How is it demonstrated that the planets move round t sun?

How are the motions of the earth in its orbit proved?

How is it proved that the Earth is of a globular form?

What is the *axis* of the earth?

What are the poles? and what the *equator?*

What are the *arctic* and *antarctic* circles?

What are the *tropics?*

What are the *zones?*

What is *latitude*, and what is *longitude?*

Explain the figure of the *celestial* globe?

What are the *poles* of the *horizon*, and what are they calle

What is meant by *meridian?*

What is *altitude*, what *azimuth*, and what *amplitude?*

What is meant by *declination*, and what by *right ascensio*

n are two planets said to be in *conjunction* and when in
ion?
n is the celestial sphere said to be *right*, *oblique*, or pa-

is *day* and *night* produced?
long is the earth in performing a revolution round the

t are the 12 *signs* of the *zodiac*?
t are the names of the signs, and which are *north* and
outh of the equator?
ain figure 64. What is the *ecliptic*?
t is the quantity of the angle made by the inclination
cliptic to the equator?
hat is the diminution of the obliquity of the ecliptic

t is the *nutation* of the earth's axis, and to what cause
ng?
may the difference of *longitude* in two places be found?
ain this.
ain prop. 210, also 211, and 212.
t causes the succession of seasons?
t is the figure of the earth's orbit?
t occasions twilight?
ain.
is it that we see the sun before he actually rises above
zon?
t is a *natural* day?
t is equation of time?
t is meant by mean, or apparent time?
t is the shape of the sun, and where is he placed?
t is his diameter?
he sun an atmosphere?
t is the calculation of Euler in regard to the compara-
it of the sun?
has the period of the sun's revolution about its axis
termined? What is this period?
t is Dr. Herschel's opinion of the height of the sun's at-
re?
t comparative quantities of matter does the sun and
contain?
much larger is the sun than the earth?
t is the probability that the sun is inhabited?
t is the distance of the sun from the earth?

Why are the asteroids called *telescopic* planets?

Explain figure 67.

What is meant by *aphelion* and *perihelion* distance?

What is *apogee* and *perigee*?

How will you show that a planet does not proceed in i bit with an equable motion?

What is a planet's *anomaly*?

Calculate the true place of a planet.

What is meant by the *equation* of a planet's centre?

What is a planet's *elongation*?

What is *periodic time*? and what is meant by *tropical* *sidereal revolution*?

What is a planet's *direct* motion, and why does it some appear *stationary*, and sometimes to move in a contrary d tion?

What are the *nodes*?

What is the diameter of *Mercury*?

What is the period of its sidereal revolution?

What is the greatest elongation of this planet from the

What is meant by its transit?

How much greater is the sun's heat and light at Me than with us?

What is the diameter of Venus?

What is the period of its sidereal revolution?

What is its period of revolution on its own axis?

When does Venus appear brightest?

When is this planet the morning and when the ev star?

What is the diameter of the earth?

What are the periods of its two revolutions?

What effect does its *centrifugal* force have on the weig bodies?

If the motion of the earth was seventeen times greater it is, what would be the effect on the weight of bodies?

What is the velocity with which a place moves per mi at the equator?

Calculate the velocity of Philadelphia.

What is the shape of the earth?

What is the difference between the *equatorial* and the diameter of the earth?

How is it determined that the earth is flattened at the p

Why are bodies heavier at the poles, than at the equa

Why is the *periodical* year longer than the *tropical*?

What causes the *precession* of the equinoxes?

How often does the *tide* rise and fall?
What is the cause of tides?
Draw a figure illustrating the theory of tides.
Why are the tides greatest at the new and full moons? and why least at the first and last quarters, and why are they highest of all about the time of the equinoxes?
Explain prop. 220.
What is the diameter of Mars?
What is its period of revolution about its axis, and what is its sidereal period?
What are the names and diameters of the several *asteroids*?
What is the sidereal period of each?
What is said of the origin of asteroids?
What is the diameter of Jupiter?
What is its diurnal, and what its sidereal period?
How many satellites has this planet?
What is said of Jupiter's belts?
What is the diameter of Saturn?
What is its diurnal, and what its sidereal period?
How many *moons* has Saturn?
What is said of Saturn's ring?
To what distance does the atmosphere of Saturn extend?
What is the diameter of Herschel, what its sidereal revolution?
When and by whom was this planet discovered?
Mention the names of the planets in succession, beginning with that nearest the sun.
What is an easy distinction between a planet and a fixed star?
What are secondary planets?
Why are the motions of the secondary planets less uniform than those of their primaries?
What is the diameter of the moon?
What its mean distance from the earth?
What is the period of its sidereal revolutions?
What is meant by *synodic* revolution?
What is meant by the moon's *Syzygies*?
Explain prop. 243, making use of the plate which illustrates it.
Why is the moon sometimes invisible when it is above the horizon?
How many days complete the year at the moon?
How many of our days is equal to one at the moon?
Explain prop. 247.
What is said of the excentricity of the moon's orbit?

How is it proved that the moon is diversified with hills and valleys?

What does Dr. Herschel say in regard to the mountains in the moon, and the volcanoes which he saw there?

What occasions an eclipse of the moon?

Illustrate this by explaining the figure.

If the earth were as large as the sun, what different phenomena would happen in regard to eclipses?

When is an eclipse of the moon *partial*, and when *total*, and what occasions this difference?

What are the relative positions of the sun, moon, and earth, when an eclipse of the *sun* happens?

When does a total eclipse of the sun happen, and what occasions it?

Why is there not an eclipse of the sun at every new moon?

What is the average number of eclipses per year, of the sun and moon?

Explain the phenomena of the *harvest* moon.

What are *comets*?

How many comets are known to return at certain periods?

What is meant by the *parallax* of a heavenly body?

What is the *diurnal parallax*?

How are the parallaxes of the planets calculated? Explain the figure.

How are the relative distances of the planets from the sun determined?

How do you measure the distance of any planet from the sun? What is the rule?

Find the periodical time of a planet.

Account for the curvilinear motions of the planets.

Explain prop. 279.

Why are some of the stars called *fixed stars*?

How is it proved that the fixed stars shine with their own light?

What number of stars are visible at any one time to the naked eye?

What is said of the distance and number of the fixed stars

What is the use of dividing the stars into constellations?

Are all the stars included in the several constellations?

What gives the appearance called the *milky way*?

What are the spots in the heavens called *nebulæ*?

What is said concerning the appearance of new stars?

are the principles on which the parallax of a heaven-
is determined?
have not the fixed stars a sensible annual parallax?
inference is drawn from the fact, that the fixed stars
annual parallax?

OF ELECTRICITY.

The surface of the earth and of all the bodies
hich we are acquainted, is supposed to contain
ess a power of exciting or exhibiting a certain
y of an exceeding subtile agent, *called the elec-
id or power.*

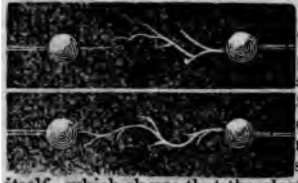
The quantity usually belonging to any surface,
ed its natural share, and then it produces no
e effects; but when any surface becomes pos-
of *more*, or of *less*, than its natural quantity, it
rified, and it then exhibits certain appearances
d to the *power*, called *electric.*

riment 1. Take a stick of sealing wax and rub it with
nd, or with a piece of flannel, or on your coat sleeve,
ill have the power of attracting small bits of paper, or
ry light substances, when held near them.

a clean and dry glass tube be rubbed several times up-
nd downwards, and then presented to any small light
e, it will immediately attract and repel them alter-
or a considerable time. The tube is then said to be

a glass tube be rubbed several times in the dark, and
ught within about half an inch of the finger, a lucid
ill be seen between the finger and the tube, accompa-
h a snapping noise, and the finger at the same time
ceive the sensation of a prick from a pin. The attrac-
ulsion, sparkling, and noise, are the effects of electrici-
are denominated electrical appearances.

The following figure represents the appearance of Electricity.



4. If an oblong pie
tal, such as a poke
pended by means of
string, and the exc
tube be presented to
end, then the lower
metallic body will e
same phenomenon a
itself, which shews that the electric fluid passes thi
metal.

5. If instead of the metallic body, a stick of glass, wax, be suspended, none of these phenomena will b ed, which proves that the electric fluid does not pas these substances.

287. All those bodies which transmit or electricity from one surface to another, are ca *ductors*; and those surfaces that will not trar electric power, are called *electrics* or *non-co*

288. The metals, semi-metals, and metal are conductors of electricity; so are charcoa and other fluids, except the aerial fluids and most all saline, and many earthy substances, wise *non-electrics* or *conductors*.

289. The following substances are *elec non-conductors*, viz. vitrified substances, am phur, resinous substances, wax, silk, cotton, wool, hair, paper, elastic fluids, sugar, oil, oxydes, animal and vegetable ashes, dry v substances, &c.

290. When a surface is supposed to have n its natural quantity of this fluid, it is said to be *ly* electrified; when it is supposed to have l its natural share, it is said to be *negatively* el

291. When any electrified *conductor* is surrounded by *non-conductors*, so that the fluid cannot pass from the conductor along co to the earth, it is said to be *insulated*.

Exp. The human body is a good conductor of e *but if* a person stand on a cake of resin, or on a sto

by glass legs, the electric fluid cannot pass from him to the rth; and if he is touched by another standing on the ground, will exhibit sparks.

292. The principal method of exciting the electric iid is by *contact*, *pressure*, or *friction*. When an ectric and non-electric are rubbed against each her, electricity is excited, and the electric power isses from the non-electric or conductor, to the ectric or non-conductor.

Exp. 1. If a smooth glass tube be rubbed with the hand, e electric fluid will leave the hand, and pass upon the tube, iich will then have more than its natural quantity.

2. And if the finger, or any conducting substance, be presated to the tube, the electricity will then pass to it.

Obs. Certain changes in the forms of substances, are alays connected with electrical effects. Thus, when vapour is rmed, or condensed, the bodies in contact with the vapour beme electrified. If, for instance, a plate of metal be strongly ated, and *a drop of water be then poured upon the plate*, at e moment the water rises in vapour, the gold leaves of the ectrometer will diverge with negative electricity. Sulphur, ter being melted, becomes strongly electrical during the ne of congelation.

293. Two surfaces, both positively, or both negavely electrified, mechanically *repel* each other; and ro substances, of which one is positively, and the her negatively electrified, mechanically *attract* each her.

294. If any person who is *insulated*, rubs a glass ibe, the person and the glass tube will become elecified, and be capable of attracting and repelling light odies; but the electricity of the person will differ om that of the tube.

Exp. 1. Let two cork balls, connected by a linen thread, be ld by a silk thread, attached to the middle of the former, at me distance from a wall; then bring the excited tube near e balls, and it will first appear to attract, and soon after repel em; this apparent repulsion will continue for a considerae time, though the tube be removed.

2. Let another pair of cork balls be brought in contact with e insulated person, and they will appear to repel each other.

3. But if the two pair of balls be brought near, they will tract each other, and the electrical power will disappear

which shews that there are two electricities, one reverse of the other, and seeming to have what wants.

4. If the insulated person rub a stick of sulphur or sealing-wax, that substance will acquire the which, in the preceding experiment, was acquired sulated person.

5. Hence *positive* and *negative* electricity have been called *vitreous* and *resinous*.

295. Opposite electricities always accomp other, for if any surface become positive, th with which it is rubbed becomes negative ; surface be rendered positive, the *nearest* co surface will become negative.

296. When one side of a metallic or othe tor receives the electric fluid, its whole surf stantly pervaded ; whereas when an electri sented to an electrified body, it becomes e on a small spot only.

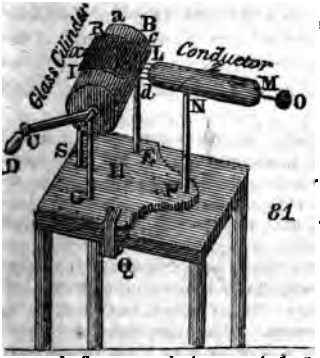
Obs. There is a stone found in many parts of called *tourmalin*, which is sometimes crystalized sided prism, terminated by a three-sided and a six-s mid ; when this substance is gently heated, it becc trical, and one extremity, that terminated by the pyramid, is positive, the other is negative ; to a c tent, its electricities are exalted by increasing the ture ; when it begins to cool, it is still found elec the electricities are changed ; the pyramid, befor is now negative, and vice versa. When the stone siderable size, flashes of light may be seen along i There are other gems and crystalized substances, v sess a property similar to that of the tourmalin. nous appearance of some diamonds, when heated, depends upon their electrical excitation. The called the *boracite*, which is a cube, having its edg gles defective, becomes electrical by heat, and in o presents no less than eight sides, in different st positive, four negative ; and the opposite poles are rection of the axis of the crystal.

297. If to one side of an electric, viz. a glass, you communicate positive electricity, t site side will become negatively electrified, *plate* is then said to be charged.

Obs. The positive and negative electricities, in the above case, cannot come together, unless a communication, by means of conductors, is made between the sides of the glass; and in like manner as a plate of glass is charged, so the plate of air lying between any electrified surfaces is always charged.

298. When two surfaces oppositely electrified, are united, their powers are destroyed, and if their union be made through the human body, it produces an affection of the nerves called *an electric shock.*

299. Machines have been contrived for rubbing together the surfaces of electrics and non-electrics, and for collecting the electric fluid, when so excited.



81

Illus. 1. Fig. 81, represents an *electrical machine.* G E F is a strong board, which supports all the parts of the machine, and which may be fastened to a table by means of one or more iron, or brass clamps, as Q. The *glass cylinder d* B is supported by the *two glass legs*, G and E. IR is the rubber of leather, and silken flap. The rubber is spread with an amalgam of mercury and zinc, or tin. The rubber or cushion is fastened to a spring, which proceeds from a socket cemented on the top of the *glass pillar* S. The lower part of this pillar is fixed into a small board, which slides upon the bottom board of the machine, and by means of a screw-nut and a slit at H, may be fixed more or less forward, in order that the rubber may press more or less upon the cylinder. NF is *a glass pillar*, which is fixed in the bottom board, and supports the *prime conductor* ML of hollow brass, or tin plate, or coated wood, which has a collection of *pointed wires* at L, and *knobbed wire* at M. From the *brass knob* O a longer spark may be drawn with the hand than from any other part of the conductor.

2. When the cylinder is turned swiftly, the friction of the glass against the rubber causes the electric fluid which was up-

on the rubber to pass to the glass, from whence it is conve to the points of the prime conductor, which are presente every part of the cylinder in succession. If one end of chain be put on the knob x and the other end hang on ground, there will then be a constant supply of the elec fluid to the prime conductor, which will be discharged in sp to any body presented to it. The *rubber* is re-supplied by m of the surfaces in immediate contact, and these again are sup ed by the general mass of the fluid that is lodged on the ea

300. Bodies or surfaces, that are charged with same electricity, appear to *repel* each other; bu one have more and the other less than its share, tl will appear to *attract* one another.

Exp. 1. If a tuft of feathers be hung on the prime condu LM, fig. 81, the moment they are electrified by turning wheel of the machine, they will endeavour to avoid one an er and stand erect: because, being all electrified by the sa electricity, they repel each other.

2. A large feather will, if placed in the hole z, when machine is worked, become beautifully turgid, expandin fibres in all directions: and they collapse when the electri is taken off, by presenting any conducting substance to th

3. Excite a glass tube eighteen or twenty inches long, t present to it a small feather, which will first have the app ance of being attracted by it, and afterwards jump from If no other body happens to be in the way, it will tend tow the ground; but if the tube be held under it, it will be repelled, and may be driven about for a considerable tim

4. Suspend a plate of metal from the conductor, and und neath it, at the distance of about three or four inches, another plate of the same size; upon the lower one sn feathers, pieces of paper, &c. may be placed; these will soon as the machine is worked, jump to the plate, from wh they will be repelled and fly to discharge themselves u the lower plate, after which they will be attracted and pelled again, and so continue till the electricity of the up plate is completely discharged.

5. If two balls made of cork, or the pith of elder, ab the size of large peas, be fastened to silk threads, they w hang parallel to each other, and be in contact; but wh brought near the electrified prime conductor, they will stro ly repel each other.

6. These balls, in their electrified state, shew whether the electricity is positive or negative; for if it be positive, by applying an excited stick of sealing-wax, the thread will collapse; but, if it be negative, the sealing-wax will make them recede still farther.

301. A pair of cork or pith balls, or pieces of gold-leaf, are used to discover the presence or strength of electricity, and denominated an *electrometer*.

82

Exp. Fig. 82, represents a *quadrant* electrometer, which may be fixed in the hole *s* of the prime conductor, fig. 81. It consists of a very light rod, and pith ball A, turning on the centre of a semicircular B. According to the strength of the electricity the pith ball flies up, and the scale marks the degree in which the prime conductor is electrified.

302. If a surface, containing only its natural share of electricity, be brought near a body that is electrified, positively or negatively, a part of the opposite electricity, in the form of *a spark*, will force itself through the air, from the latter to the former.

303. When two surfaces, one electrified positively the other negatively, approach each other, the superabundant electricity rushes violently from one to the other, to restore the equilibrium.

Obs. It rushes, says Sir Richard Phillips, through the nearest point of physical contact, usually some spicula on the surface, and in this spicula or point is consequently concentrated the entire power of the opposing surfaces. Hence the positive side exhibits brushes at the points, diverging, diffusing, and vanishing; and the negative a concentrated and uniting star.

304. If an animal be placed so as to form part of this circuit, the electricity in passing through it produces a sudden and violent sensation, called the *electric shock*.

305. The motion of electricity, in passing from a positive to a negative body, is so rapid, that it appears to be, in truth must be, *instantaneous*.

Obs. The writer referred to above, says it is analogous to light and shade, and therefore necessarily coincident.

306. When any part of one side of a glass is present ed to a body electrified positively or negatively, tha side of the glass becomes possessed of the *contrar* kind of electricity to the side of the body it is present ed to, and the other side of the glass is possessed (the same kind of electricity as the other body.

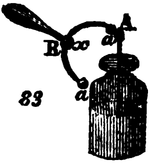
Exp. If the knob O of the prime conductor, fig. 54, be elec trified positively, and a pane of glass be presented to the sid next to O, it will be negatively electrified, and the other sid will be positively electrified.

307. Electricity may be communicated to th whole surface of glass, or any part of it, if it be co vered with a metallic substance, as *tin-foil*; and th is called *coating* the glass.

308. If a conducting communication be made be tween both sides of the glass thus *coated* and *charge* with electricity, a discharge or explosion takes plac

Obs. Glass of any form, provided it be sound, will answ the purpose; but cylindrical jars are chiefly used.

309. A glass bottle, or jar properly coated for ele trical purposes, is called a *Leyden* phial, or jar, fro the city where this property was first discovered.



83

Illus. Fig. 83, represents a Leyden ja coated with tin-foil on the inside and outsid within about three inches of the top of its cy lindrical part, and having a wire with a roun brass knob, or ball, A, at its extremity. Th wire passes through the cork, or woode stopper, and at its lowest extremity is a pie of chain that touches the inside coating in se veral parts. To charge this jar, a communication is made be tween the electrical machine and the brass knob A, while th outside of the jar communicates with the earth by the tab or the hand.

Exp. 1. Bring the knob A of the jar near the prime conduc or, and after a few turns of the machine the jar will be charge that is, the inside of the jar will be positively, and the outsi negatively electrified; or if the inside is negatively, the ou side will be positively electrified. R is a discharging rod, whic is used to convey the superabundant electricity from or

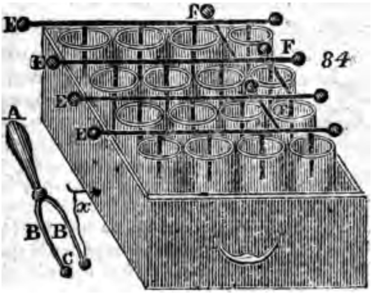
side to the other, where there is less than the natural share. The discharging rod consists of two brass knobs *a a* attached to wires, which move round a joint *x*, fixed to a glass handle R.

2. When one of the knobs is applied to the ball A, and the other to the outside coating, a communication is made between the outside and inside of the jar, by which the equilibrium is instantly restored by the superabundant electricity passing from one side to the other, appearing in the form of a vivid flash, accompanied with a loud report.

3. A shock may be taken by putting one hand to the outside coating, as at *a*, and bringing the other to the knob A.

4. Any number of persons may receive the shock together by laying hold of each others' hands, the person at one end touching the outside of the jar, and the person at the other end bringing his hand near the knob A. If there were a hundred persons so situated, they would every one feel the shock at the same instant. The electric fluid may be thus conveyed many miles in a moment of time.

310. Several Leyden jars, connected together by making a communication between *all the outsides*, and another communication between *all their insides*, form an ELECTRICAL BATTERY.



84

Illus. Fig. 84, represents a battery, consisting of sixteen jars, coated with tin-foil, and disposed in a proper box. The wires, which proceed from the inside of every four of those jars, are screwed, or fastened, to a common horizontal wire E, which is knobbed at each extremity, and by means of the wires F, F, F, the inside coating of 4, 8, or 12, or of all the sixteen

Exp. 1. A very slender wire, as x, being made part of the circuit, will, by the discharge of the battery, in become red hot. It sometimes melts into small glob ferent sizes.

2. If between two slips of window-glasses som be placed, and the slips of glass be pressed firml and the shock from a battery be sent through them leaf will be forced into the pores of glass.

3. If the gold-leaf be put between cards, and a str be passed through them, it will be completely fuse

4. Gunpowder may also be fired by the electric

312. Metallic points attract the electri bodies silently, which renders them of a sup in defending buildings from *lightning*.

313. When electricity enters at a poin pears in the form of a star ; but when it goe a point, it puts on the appearance of a brush

Obs. Delicate apparatus may be put in motion b tric fluid when issuing from a point; hence we hav *orreries, mills, &c,*

314. *Lightning* is the rapid motion of va of electric matter, and *Thunder* is the noise

thunder, which is more or less intense, and of longer or shorter duration, according to the quantity of air acted upon, and the distance of the place where the report is heard from the point of its discharge.

315. When the electric fluid passes through highly rarefied air, it constitutes the *aurora borealis*, or *northern lights*. Most of the great convulsions of nature, such as earthquakes, whirlwinds, hurricanes, &c. are generally accompanied by, and often dependent upon, the power of electricity.

Obs. The water-spout is probably the result of the operation of a weakly electrical cloud, at an inconsiderable elevation above the sea, brought into an opposite state; and the attraction of the lower part of the cloud, for the surface of the water, may be the immediate cause of this extraordinary phenomenon. The cerruscations of the aurora borealis and australis, precisely resemble strong artificial electricity, discharged through rare air; and as the poles are non-conductors, being coated with ice or snow, and as vapour must be constantly formed in the atmosphere above them, the idea of Franklin is not improbable, that the auroras may arise from a discharge of electricity, accumulated in the atmosphere near the poles, into its rarer parts; though other solutions of the phenomena may be given on the idea, that the earth itself is endowed with electrical polarity; or that the motions of the atmosphere produce the effect.

QUESTIONS ON ELECTRICITY.

What parts of bodies contain the *electric fluid*, internal or external?

Under what circumstances are the effects of the electric fluid shown?

When a piece of sealing-wax, or glass, is rubbed, why does it gain the power of attracting or repelling light bodies?

How is it proved that the electric fluid will pass through a metal?

How is it proved that it will not pass through glass, or sealing-wax?

What substances are *conductors* and what are *non-conductors* of this fluid?

When a surface is supposed to have more than its natural quantity of this agent, what is said of it?

When a surface has less of the fluid how is it distinguished from one which has more?

When is a body said to be *insulated?*

Under what circumstances can the human body be made to give an electric shock?

What are the principal methods of exciting the electric fluid?

When do two electrified bodies repel each other? and when do they attract each other?

How is it shown that when an insulated person rubs a glass tube the person is electrified differently from the tube?

What is meant by *vitreous* and *resinous* electricity?

When electricity is excited by rubbing two surfaces together, are they both in the same electrical states?

What is meant by *electrics?*

What is said of the stone called *tourmalin?*

When two surfaces oppositely electrified are united what is the effect?

Explain the uses of the different parts of the electrical machine.

What is an *electrometer?*

If a surface containing its natural share of electricity be brought near one which is positively or negatively electrified, what is the effect?

Does the electric fluid spread on glass?

How can it be communicated to a part of the surface only?

When is a piece of glass said to be *coated?*

What happens when a communication is made between both sides of a coated and charged glass?

What shaped glasses answer best for these experiments?

What is a *Leyden phial?*

Explain its structure and the method of charging and discharging it?

What constitutes an *electrical battery?*

Mention some of the striking experiments made by the battery.

How are buildings defended from the effects of lightning?

When does electricity appear as a *star,* and when as a *brush?*

How can machinery be put in motion by electricity?

What is *lightning?*

What is *thunder?*

What constitutes the *aurora borealis?*

What is the cause of the *water spout?*

GALVANIC ELECTRICITY.

316. GALVANISM is another mode of exciting electricity. In electricity the effects are chiefly excited by mechanical action; but the effects of galvanism are produced by the chemical action of bodies upon each other.

317. The nerves and muscles of animals are most easily affected by the galvanic fluid; but combined in the voltaic battery, it possesses surprising powers of chemical decomposition.

Obs. 1. In 1791, Galvani, of Bologna, discovered that a dead frog may have its muscles brought into action by very small quantities of electricity. He also discovered that the same motions may be produced in the dead animal, merely by making a communication between the nerves, and the muscles, by means of conducting substances.

2. Some fishes have the property of giving shocks analogous to those of artificial electricity; namely, the *torpedo*, the *gymnotus electricus*, and the *silurus electricus*. If the torpedo, whilst standing in water, but not insulated, be touched with one hand, it generally communicates a trembling motion or slight shock to the hand. If the torpedo be touched with both hands at the same time, one hand being applied to its under and the other to its upper surface, a shock will be received exactly like that occasioned by the Leyden phial. The shock given by the torpedo when in air, is about four times as strong as when in water; and when the animal is touched on both surfaces by the same hand, the thumb being applied to one surface, and the middle finger to the opposite, the shock is felt much stronger than when the circuit is formed by both hands. The gymnotus electricus, or electrical eel, possesses all the electric properties of the torpedo, but in a superior degree. When small fish are put into the water wherein the gymnotus is kept, they are generally stunned or killed by the shock, and then they are swallowed if the animal be hungry. The strongest shock of the gymnotus will pass a very short interruption of continuity in the circuit. When the interruption is formed by the incision made by a penknife on a slip of tin-foil that is pasted on glass, and that slip is put into the circuit, the shock, in passing through

that interruption, will shew a small but vivid spark,] to be seen in a dark room. The gymnotus seemed alsc possessed of a sort of *new sense*, by which he knows w the bodies presented to him are conductors or not. T has been ascertained by a great number of experiment:

Exp. 1. If a living frog, or a live fish, as a flounder, a slip of tin-foil pasted on its back, be placed upon a p zinc, whenever a communication is formed between t and tin-foil, the spasms of the muscles are excited.

2. If a person place a piece of one metal, as a half above, and a piece of some other metal, as zinc, be tongue, by bringing the outer edges of these pieces i tact, he will perceive a peculiar taste, and in the da see a flash of light.

3. If a person in a dark place put a slip of tin-foil u bulb of one of his eyes, and a piece of silver in his mo causing these pieces to communicate, a faint flash will before his eyes.

318. The conductors of the galvanic fluid : vided into the *perfect* and *imperfect*. The conductors consist of metallic substances anc coal.—The *imperfect* conductors are water an dated fluids, as the acids, and all the substanc contain these fluids.

319. The simplest galvanic combinations mu sist of three different conductors, not wholly class. When two of the three bodies are of tl class, the combination is said to be of the first when otherwise, it is said to be of the second.

320. It seems to be indispensably requisite, ple galvanic circles, that the conductors of on shall have some chemical action upon those of the

Exp. If a piece of zinc be laid upon a piece of cop upon the copper a piece of card or flannel, moistened solution of salt water, a *circle* of the first class is form then if three other pieces be laid on these in the sam and repeated several times, the whole will form a pile *ry* of the *first* order.

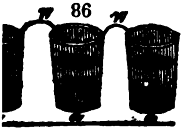
321. When the three bodies which form a g circle of the first order are laid on one another, t

ınd the under one not touching, these two ex-
es form opposite electric states.

2. The galvanic effects may be increased to any ;e, by a repetition of the same simple galvanic ›ination, and these repeated combinations are d galvanic piles or batteries, which may be con- ted of various forms.

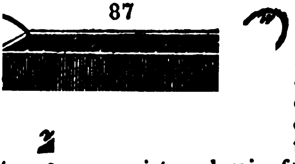
p. 1. Take a number, say twelve plates of silver, and ıme number of pieces of zinc, and also of woollen cloth, ıst having been soaked in a solution of sal ammoniac in · ; with these a pile is to be formed, viz. a piece of silver, ce of zinc, a piece of cloth, and thus repeated. These › be supported by three glass rods placed perpendicular- th pieces of wood at the top and bottom, and the pile is lete, and will afford a constant current of electric fluid, gh any conducting substance ; thus, if one hand be ap- to the lower plate, and the other to the upper one, a ε will be felt, which is repeated as often as the contact is wed. But the plates will soon become *oxydated*, and re- ؛ cleaning in order to make them act.

86



2. Another battery consists of a row of glasses of any shape, *a a*, fig. 86, containing a solution of salt and water; into each of these, except the two on the outside, is put a plate of zinc *z*, and another of silver *x*; ؛ plates communicate by means of the wires *w w*, and are stened, that the silver, *x*, in one glass is connected with ;inc, *z*, in the other: when one hand is dipped into the glass, and another in the last, a shock is felt. The glasses be of any number.

87



3. The most convenient kind of battery consists of a trough B, fig. 87, made of baked wood, three inches broad, and about as deep; in the sides of the trough are grooves oppo- to each other ; into each pair of grooves is fixed by cement

a plate of zinc and silver soldered together, and in
of silver and zinc; the cement must be filled in so
vent any communication between the different ce
cells are to be filled with water, or with a solution
and nitrous acid, when, a communication being
tween the first and last cell, by means of the hands,
shock is felt, and will be repeated as often as the c
renewed.

4. Several persons, by joining hands, having firs
them with water, may receive the shock.

5. If plates of copper and zinc, two or three inche
and pieces of cloth of the same size, soaked in a so
salts of sal ammoniac, or nitre, be arranged in the
copper, zinc, moistened cloth, and so on, and made in
sulated pile, of which the series are two hundred, se
markable phenomena will occur. When one hand i
to the bottom of the pile, and the other to the top, bo
being moistened, a shock will be perceived. When
lic wire, having a bit of well burned charcoal at its
ty, is made to connect the two extremities of the pile,
will be perceived, or the point of the charcoal will be
nited. A wire connected with the top of the pile, br
contact with a sensible electrometer, will cause the
diverge; and, by removing the wire and applying
glass to the electrometer, it will be found that the el
is positive; a wire connected with the bottom of the
affect it with negative electricity; a wire from the m
the pile will have no influence on the instrument.
of platina from the extremities of the pile be introdu
water, or into two portions of water connected by mo
stances, oxygen gas will separate at the wire exhibit
positive electricity; and hydrogen gas at the wire ex
the negative electricity; and the proportions are such
the proper circumstances exist, that they will produ
ter when exploded by the electrical spark, that is, the
of hydrogen will be to that of oxygen, as two to one.
same wires be introduced into a strong solution of su
or phosphoric acid, or into metallic solutions, oxygen w
rate at the positive surface, the inflammable, or m
matter contained in the solution, at the negative surfa

323. The spark from a powerful galvanic b
acts upon and inflames gunpowder, charcoal,
and other inflammable bodies, melts all metals, di
es diamonds, &c.

Exp. Fill the battery (fig. 87,) with water and nitrous acid, in the proportion of nine parts of water and one of acid, and wipe the edges of the plates very dry, then the wires *w w* are to be fastened to pieces of copper, and put into the outer cells: *a a* are little glass tubes to hold the wires by. Bring the ends of the wires together on the plate of glass *x*, and a spark will be perceived: if gunpowder be laid on the glass between the points of the wires, it will be exploded.

2. Gold and silver leaf may be inflamed in this way; Dutch gold burns with a beautiful green light; silver with pale blue; gold with yellow light.

3. The most powerful combination that exists, in which the greatest number of alterations is combined with extent of surface, is that in the laboratory of the *Royal Institution*. It consists of two hundred instruments, connected together in regular order, each composed of ten double plates arranged in cells of porcelain, and containing in each plate 32 square inches; so that the whole number of double plates is 2000, and the whole surface 128,000 square inches. This battery, when the cells were filled with sixty parts of water, mixed with one part of nitric acid, and one part of sulphuric acid, affords a series of brilliant and impressive effects. When pieces of charcoal about an inch long, and one-sixth of an inch in diameter, are brought near each other, (within the thirtieth or fortieth part of an inch) a bright spark is produced, and more than half the volume of the charcoal becomes ignited to whiteness, and by withdrawing the points from each other a constant discharge takes place through the heated air, in a space equal at least to four inches, producing a most brilliant ascending arch of light, broad, and conical in form in the middle. When any substance is introduced into this arch, it instantly becomes ignited; platina melts as readily in it as wax in the flame of a common candle; quartz, the sapphire, magnesia, lime, all enter into fusion: fragments of diamond, and points of charcoal and plumbago, rapidly disappear and seem to evaporate in it. Such are the decomposing powers of electricity, that not even insoluble compounds are capable of resisting their energy: for glass, sulphate of baryta, fluor spar, &c. when moistened and placed in contact with electrified surfaces from the voltaic apparatus, are slowly acted upon, and the alkaline, earthy, or acid matter carried to the poles in the common order. Not even the most solid aggregates, nor the firmest compounds, are capable of resisting this mode of attack; its operation is slow, but the

2. Another galvanic circle is seen by the discol
a silver spoon in eating eggs; the saliva and fluid e
ductors of the second class, and the silver of the fir

3. Pure mercury retains its splendour a long tin
it be amalgamated with tin, and it is quickly oxyd

4. Works of metal, the parts of which are soldere
soon tarnish in the places where the metals are join

5. The nails and the copper in the sheathing o
soon corroded about the place of contact. These
fects of galvanism.

325. The effects of galvanism on metal
are greatly increased by using plates of a la
and on the contrary the shock is increased
plying the pairs of plates.

Obs. 1. The shock of a battery containing 80 or
plates, of three or four inches in diameter, is such a
sons would be willing to bear more than once. A
time, such a battery produces but feeble effects w
through a metallic wire. On the contrary, if one o
of plates containing the same extent of surface be
sensation it gives is hardly to be felt, while it will c
metallic wire of considerable size.

2. Professor Hare, of Philadelphia, has invented

galvanic influence and the nervous influence. The galvanic influence being capable, in some instances of supplying the place of the nerves.

Obs. 1. Dr. Wilson Phillip in his inquiry into the laws of the vital functions has shown, that if a nerve be divided, and a stream of galvanism be directed along and through the part, whose functions depend on this, that the function was performed as usual. Thus on dividing the nerves which are distributed to the stomach, the process of digestion ceases though the animal continues to live for some time. But on supplying the place of the nervous power by the galvanic influence, digestion was performed as usual.

2. In the same way it was found, that when the nerves distributed to other parts were divided, and the part became palsied for want of the nervous power, a stream of galvanism rightly directed would again in a good degree restore the action of that part.

3. Dr. Phillip having conjectured that the heat of animals depended on the influence of the nerves, wished to observe how far the galvanic power might produce this effect. For this purpose some blood was drawn from two animals of the same kind and temperature into two small cups. The blood in one of the cups was submitted to the galvanic influence, while the other was placed under the same circumstances, except in this respect. Now if the galvanized blood remained warm the longest, or had its temperature increased, it would show an additional analogy between the galvanic and nervous energy, if indeed animal heat depends on the latter. The experiment gave a decided proof that the galvanic power had some influence on the temperature of newly drawn blood, for that portion which was submitted to its action, not only remained warm longer than the other, but its temperature was actually raised several degrees.

4. From the difficulty in breathing, which animals experience on depriving the lungs of a portion of their nervous influence, Dr. Phillip was led to make trial of galvanism in *asthma*, suspecting in this disease there might be a want of nervous power. The inference which he draws from a very considerable number of trials on persons afflicted with this disease, is, that there is a difficult transmission of the nervous influence, through the nerves which supply the organs of respiration, and that in a great majority of cases the asthma may be permanently cured, or at least relieved by galvanism.

327. Galvanism has a peculiar and most surpris ing effect on the muscles of dead animals, their limb being thrown into violent motion by it a considerabl time after the life of the animal is extinct.

5. The most striking effects of galvanism on the huma frame after death, were exhibited at Glasgow a few years sinc

The subject on which these experiments were made, wa the body of the murderer Clydesdale, who was hanged at th city. He was suspended an hour, and the first experiment wa made in about ten minutes after he was cut down. The gal vanic battery consisted of 270 pairs of four inch plates.

The subject was prepared for the first experiment by mal ing an incision into the nape of the neck, and removing part of the *atlas vertebre*, so as to bring the spinal marrow int view; at the same time, another incision was made in th left hip so as to lay above the *sciatic* nerve and another sma one in the heel. The pointed rod connected with one end the battery was now made to touch the spinal marrow, whil the end of the other was placed in contact with the sciat nerve. Every muscle of the body was immediately agitat with convulsive movements resembling a violent shudderi from cold. On moving the rod to the heel, the knee bei previously bent, the leg was thrown out with such violence, nearly to overturn one of the assistants, who in vain attempt to prevent its extension.

The next experiment was made by directing the galvan power in the course of the *phrenic* nerve, which goes to t principal muscle of respiration, the diaphragm. The effec were far more striking than before. "Full, nay, laborio breathing," says Dr. Ure, "instantly commenced. The ch heaved and fell; the abdomen was protruded, and again co lapsed with the relaxing and retiring diaphragm."

In the judgment of many scientific gentlemen who witne ed the scene, this respiratory experiment was, perhaps, t most striking ever made with a philosophical apparatus. T next experiment was made by applying one of the wires to t *supra obital* nerve under the eye brow, and the other to t heel. Most extraordinary grimaces were made; "eve muscle in the countenance was simultaneously thrown i fearful action; rage, horror, despair, anguish, and ghas smiles, united their hideous expressions in the murdere face." At this period, several of the spectators were forced leave the room from terror or sickness, and one gentlem fainted. "In the last experiment, one of the wires was ma

to touch the spinal marrow at the nape of the neck, and the other an incision in the top of the fore finger; the first being previously clenched. The finger extended instantly, and from the convulsive agitation of the arm, the finger seemed to point out the different spectators, some of whom thought he had really come to life."

QUESTIONS ON GALVANISM.

What is meant by *Galvanism?*

What parts of animals are most easily affected by the galvanic fluid?

When, and by whom was the galvanic principle discovered?

What effect does it have on dead animals?

What animals have the power of giving electric shocks?

What is the experiment with the living frog, or fish?

How are galvanic conductors divided?

What are the *perfect*, and what the *imperfect* conductors?

What are the most simple galvanic combinations?

When is the combination of the first, and when of the second order?

Do the conductors of one class have any chemical action on those of the other?

How is a battery of the first order constructed?

What parts of a pile are in opposite electric states?

How can galvanic effects be increased?

Explain the mode of constructing a galvanic battery.

What substances can be set on fire by the galvanic shock?

What fluid is used to fill a galvanic trough?

What facts in common life are explained by galvanism?

In what respect is it increased by multiplying the pairs of small plates?

What is Professor Hare's invention?

What analogy is there between galvanism and the nervous influence?

What effect does galvanism have on the temperature of warm blood?

What is said of its effects on asthma?

What is said of the effects of galvanism on the body of Clydesdale?

OF MAGNETISM.

328. MAGNETISM explains the properties of the loadstone, or natural magnet, which is a dark coloured and hard mineral body, and is found to be an ore of iron, being generally found in iron mines.

The magnetic properties of the natural magnet may be communicated to other bodies, which are then called artificial magnets. These properties can, however, be communicated to no other substances than iron or nickel.

329. The following are the characteristic properties of a magnet. 1. The magnet attracts iron and steel. 2. A magnet, if left at liberty, will point towards the poles of the earth, or very nearly so, and each end always points to the same pole. 3. When the north pole of one magnet is presented within a certain distance to the south pole of another, they will attract each other. But if a north pole of one be presented to the north pole of another, or a south to a south, they will repel each other. 4. The two poles of a magnet, left at liberty, do not lie in the same horizontal direction; one of them *inclines* towards the horizon, and of course the inclination of this causes an elevation of the other pole above it. This is called the inclination or *dipping* of the magnet. 5. Any magnet may be made to impart those properties to iron or steel.

All natural and artificial magnets, as well as the bodies upon which they act, are either iron in its pure state, or such compounds as contain it. All magnets attract iron and nickel.

Obs. 1. The action and re-action of the magnetic power are mutual and equal; for if a piece of iron, or steel, or other ferruginous substance, be brought within a certain distance of one of the poles of a magnet, it is attracted by it, so as to adhere to the magnet, and not suffer itself to be separated without an evident effort.

2. The attraction is mutual, for the iron attracts the magnet as much as the magnet attracts the iron; since if they be placed on pieces of wood or cork, so as to float upon the surface of water, it will be found that the iron advances towards the magnet as well as the magnet advances towards the iron: or, if the iron be kept steady, then the magnet will move towards it.

330. When a magnet is at liberty to move itself freely, it constantly turns the same end towards *the north pole*, and of course the opposite part towards *the south pole*, of the earth.

331. Those parts of the magnet's surface which it turns towards the poles of the earth, are called the north and south poles of the magnet.

332. The property of pointing to these poles is called its *directive power*, and when it moves to place itself in that direction, it is said to *traverse*.

333. The *magnetic meridian* passes through the poles of the magnet when standing in their natural direction. The *declination* of the magnet, or of the magnetic needle, is the angle which *the magnetic meridian* makes with the *meridian of the place*.

334. The north or south poles of two magnets *repel* each other; but the north pole of one *attracts* the south pole of another.

Exp. Place a magnetic needle upon a pin stuck on a table, and when it stands steady, place an iron bar, eight inches long, and half an inch thick, upon the table, so that one end of it may be on one side of the north pole of the needle, and near enough to draw it a little out of its natural direction. In this situation approach gradually the north pole of a magnet to the other extremity of the bar, and you will see the needle's north end will recede from the bar, in proportion as the magnet is brought nearer to the bar.

335. The inclination, or *dipping*, of the magnetic needle, expresses the property which the magnet possesses of inclining one of its poles towards the horizon, and elevating the other pole above it.

336. Any magnet may, by proper methods, be made to impart its properties to iron, steel, or nickel

337. When a piece of iron is brought witl tain distance of one of the poles of a magne tracted by it; the attraction is strongest at t

338. The magnetic attraction is not in the minished by the *interposition* of any bodies ex

Exp. 1. Suppose a magnet placed at an inch dis a piece of iron, requires an ounce of force to ren which is the same thing, suppose that the attractic each other is equal to one ounce: it will be foun same degree of attraction remains constantly though a plate of other metal, glass, paper, &c. be between the magnet and the iron, or though they l in separate boxes of glass or other matter.

2. Move steel filings placed on a brass plate, in by holding a magnet under the vessel.

3. Strew on a sheet of paper, some iron filings small magnet among them; then shake the table a the filings will arrange themselves in the way repı fig. 90. But if iron filings are shaken through a g upon a paper that covers a bar magnet, the fili arranged in curved lines.

4. Sprinkle steel dust on a a sheet of paper, und placed a magnet, or two magnets, having their pol to each other, and at the distance of about an inch.

5. A needle under an exhausted receiver, will ed at the same distance as in the open air.

339. Soft iron is attracted by the magnet ı cibly than steel, but it is not capable of pı the magnetic property so long.

340. Heat weakens the magnetic power, aı heat destroys it. The gradual addition of w magnet kept in its proper situation, incr magnetic power.

Obs. Among natural magnets, the smallest gener a greater attractive power, in proportion to their those which are larger. There have been natural m exceeding twenty or thirty grains, which would lif iron that would weigh forty or fifty times more t selves. A small magnet, worn by Sir Isaac Newto weighing about three grains, is said to have tak grains, or near 250 times its own weight, and Mr. (

seen one of six or seven grains weight, which was capable of lifting a weight of 500 grains. But magnets of two pounds and upwards, seldom lift up ten times their own weight of iron.

341. The north pole of a magnet is more powerful in the northern, and the south in the southern parts of the world.

342. When a magnet with two poles is freely suspended, or floats upon water, with no iron near it, it places itself in the magnetic meridian, and it is this principle of polarity that makes it so useful to navigate at sea.

Obs. 1. When a magnet is kept freely suspended, so that it may turn north or south, the pilot, by looking at its position, can steer his course in any required direction at sea.

2. An artificial magnet, fitted up in a proper box, is called the *magnetic needle*, and the whole together is called the *mariner's compass* See figs. 90, 91.

3. Though the north pole of the magnet always points toward the northern, and the south toward the southern parts, yet their direction is seldom in the exact direction of the poles of the earth, that is, the magnetic and the real meridian seldom coincide, and the angle which they make is called the *angle of declination*, or *variation* of the magnetic needle.

4. This declination is said to be *east* or *west*, according as the north pole of the needle is eastward or westward of the true meridian of the place.

5. At present the declination, or variation, of the magnetic needle, is about twenty-four degrees westward at London, and the dipping seventy degrees.

343. When a piece of iron is brought sufficiently near a magnet, it becomes itself a magnet. Bars of iron that have stood long in a perpendicular situation, are generally found to be magnetical.

Obs. 1. If a long piece of hard iron be made red hot, and then suffered to cool in the direction of the magnetical line, it becomes magnetical. The electric shock will often render iron magnetical; so also will lightning.

2. Artificial magnets are made by applying one or more powerful magnets to pieces of hard steel. The power of a magnet is not diminished by communicating its properties to other bodies.

3. Two or more magnets joined together may communicate

which cannot be accounted for upon this hypothesis the Doctor supposes may arise from an unequal and ir distribution of the magnetical matter. The irregular bution also of ferruginous matter in the shell may li cause some irregularities.

5. Mr. Cavallo's opinion is, that the magnetism of th arises from the magnetic substances therein contain that the magnetic poles may be considered as the cen the polarities of all the particular aggregates of the m substances; and as these substances are subject to the poles will change. Perhaps it may not be easy ceive how these substances can have changed so mat as to have caused so great a variation in the poles, th tion of the compass having changed from the east towa west about thirty-three degrees in two hundred years the gradual, though not exactly regular, change of va shews that it cannot depend upon the accidental which may take place in the matter of the earth.

6. Mr. Churchman, of America, says there are tw netic poles of the earth, one to the north and the othe south, at different distances from the poles of the ear revolving in different times; and from the combine ence of these two poles, he deduces rules for the pos the needle in all places of the earth, and at all tim

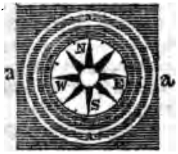
88

89

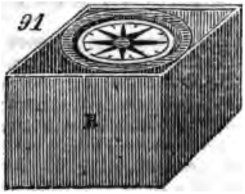
Illus. 1. A magnetic needle is represented in figs. 88 and 89, the first of which shows the upper side, and the second a side view of the needle, having a pretty large hole in the middle, to which a conical piece is adapted by means of a brass piece O, into this the agate cap (as it is called) is fastened. The apex of the hollow cap rests upon the point of a pin F, which is fixed in the centre of the box, and upon which the needle being properly balanced, turns very nimbly.

Illus. 2. A mariner's compass is represented in fig. 90 ; the box which contains the card, or fly, with the needle, is made of a circular form, either of wood, or brass, or copper. It is

90



91



suspended within a square wooden box B, fig. 91, by means of two concentric circles, called gambols, so fixed by cross axes, *a*, *a*, *a*, *a*, fig. 90, to the two boxes, that the inner one, or compass box, shall retain an horizontal position in all motions of a ship, whilst the outer or square box is fixed with respect to the ship. The compass box is covered with a pane of glass, that the motions of the card may not be disturbed by the wind. What is called the card is a circular piece of paper, which is fastened upon the needle, and moves with it. The outer edge of this card is divided into 360 equal parts or degrees, and within the circle of these divisions it is again divided into 32 equal parts, or arcs, which are called the points of the compass, or rhumbs, each of which is often subdivided into quarters.

3. There seems to be a similarity between magnetism and electricity. If two pieces of soft iron wire be led each to a separate thread, and they are hung freely, and if the north end of a magnet bar be brought under them, the wires will repel each other as in electricity. The same result would happen if the south pole of the magnet be presented instead of the north.

QUESTIONS ON MAGNETISM.

What is the *natural magnet*, and where is it found?
To what substances can magnetic properties be communicated?
What are the characteristic properties of the magnet?
What are the substances attracted by the magnet?
What are the poles of the magnet?
What is the *magnetic meridian?*
What is the declination of the magnetic needle?
Which of the magnetic poles *attract*, and which *repel* each other?
What is meant by the dipping of the needle?
Is the attraction of a magnet diminished by the interposition of any body?
How is this proved?
Which is attracted most powerfully, iron or steel?
How is the magnetic power weakened or destroyed?
How is the magnetic power increased?
When does the magnet place itself in the magnetic merid
Whas is meant by the *angle of declination*, or variation?
What is a mariner's compass?
In what cases does iron become magnetic without the u a magnet?
How are artificial magnets made?
Where does the *cause* of magnetism exist?
What is Mr. Cavallo's opinion of the cause of magnetism
What is Mr. Churchman's opinion?
How is a magnetic needle made?
Explain the figure of the mariner's compass.

GLOSSARY

OF SCIENTIFIC TERMS AND TECHNICAL WORDS.

Accelerated motion, is motion added to motion, by the constant action of an original force.
Acoustics, the science of sound and hearing.
Air-Pump, a machine for making experiments on air.
Amplitude, the point of the compass at which a heavenly body rises or sets.
Aphelion, the point of the orbit of a planet which is the most distant from the sun.
Apogee, the sun's or moon's greatest distance from the earth.
Astronomy, the science which treats of the planets, stars, and celestial motions.
Attraction, the phenomena of bodies falling together, without sensible cause.
Atmosphere, the fluid or air in which men and other animals live, and which surrounds the earth to a considerable height.
Azimuth, the bearing of any heavenly body which is above the horizon.
Barometer, an instrument for measuring the elasticity of the atmospheric air.
Cause, that which produces or appears to produce *an effect*.
Capillary tubes, which resemble hair, and exhibit peculiar phenomena of attraction on fluids.
Central forces, that composition of forces, by which bodies move in circles or curves.
Centripetal force, the force which acts from the circumference towards the centre.
Centrifugal force, the force which acts in the direction of a tangent to the circle or orbit.
Centre of Gravity, the point of any body about which all its parts balance each other.
Cohesion, the power which binds particles of matter into solid masses.
Coats of the eye, the sclerotica, the choroides, and the retina.

Conductors, classes of bodies which conduct, with differen grees of facility, the powers of heat and electricity.
Concave, a hollow surface.
Convex, a projecting surface.
Convergency, tending towards a point.
Constellations, figures which the various groups of stars supposed to resemble.
Decompose, to take to pieces, or analyze.
Declination, the distance of a heavenly body, north or sou the equinoctial.
Diagonal, the line drawn from one angle to another of figure.
Disc, the face or surface of the sun or moon.
Divergency, spreading from a point.
Divisibility, the power which exists of dividing particl matter indefinitely.
Dynamics, the science of motion, forces, or momenta.
Excentricity, in the earth's orbit; the excentricity is equ 168 ten thousandths, or .0168 of the mean distance.
Excentricity of the planet's orbit, is the distance of the from the centre of the orbit.
Ecliptic, the line in which the sun appears to move.
Eclipse of the Sun, an interception of the light of the su the earth by the intervening moon.
Eclipse of the Moon, the interception of the light of the su the moon by the intervening earth.
Elasticity, the disposition and power which bodies posse returning to their original position and shape.
Elements, any substances which cannot be decompose oxygen, nitrogen, and hydrogen; phosphorus, sulp carbon, and the earths; the metals, and the alkalies.
Equinoctial or *Equator*, the circle of the earth, which is way between the north and south pole.
Equation of time, arises from various unequal motions of sun, but chiefly from the quick motion in the earth's helion, which is 61′ 10″ per day, on January 1, and slow motion in the aphelion, which is about 57′ 11″ per day, or one fifteenth less, on July 1.
Equinoxes, the beginning of Aries and Libra, or equal and night.
Eudiometer, an instrument for measuring the purity of air
Evaporation, the passing of fluids into a state of vapour.
Focus, a central point, the place where rays of light or a n ral power converge. Its plural is *foci*.
Fulcrum, a prop on which a lever acts.

Fusion, the rendering of a solid body fluid, by the application of heat.

Gas, the elastic or expanded state of any fluid or substance formed by the action of heat.

Galvanism, the science of chemical or animal electricity, in which electrical effects are permanent without friction.

Geocentric place, the places of the planets, as seen from the earth.

Gravity, the tendency of masses of matter to fall together.

Gravity, specific, the relative weight of different bodies in regard to some standard, as water.

Heliocentric place, the places of the planets as seen from the sun.

Horizon, the line that bounds the view, where the earth and heavens seem to meet, and which cuts the heavens into two equal parts.

Humours of the eye, the aqueous, the crystalline, and the vitreous.

Hydrostatics, the science which teaches the laws of pressure and motion in fluids.

Hydraulics, the science which teaches the construction of water engines.

Hydrogen, the bases of water, 15 parts with 85 of oxygen, forming 100 parts of water, and combined with carbon, it produces the gas lights.

Hydrogen gas, the same as inflammable air, and fourteen times lighter than atmospheric air.

Inertness, the disposition which all matter has to remain in its actual state.

Infinite space, a description applied to space; because no bounds or limits can be conceived to it.

Inverse, contrary-wise, an opposite proportion.

Incidence, the point at which a ray of light strikes the surface of any body.

Jar, electrical, formed so as to condense the electric power.

Latitude of places on the earth, is their distance in degrees from the equator, northward or southward.

Latitude, in astronomy is the distance of a heavenly body in degrees from the ecliptic, northward or southward.

Lens, the name of any transparent body, the sides of which are convex or concave, for the purpose of converging or diverging rays of light.

Light, the affection or power by which distant objects are brought in contact with the eye, either by particles in rapid motion, or by vibrations of a universal medium.

Liquid, a state of substance in which, by the accession powers of heat, the particles slide easily among one ano er; without heat, all liquids become fixed or solid.

Longitude of places on the earth, is the distance of the me dian of the place from the first meridian, east or west.

Longitude, in astronomy, is the distance of a heavenly bo from the beginning of Aries measured on the ecliptic.

Matrix, the substance in which metallic ores are imbedde

Matter, the basis of all substances, constantly changing forms, but always maintaining its existence.

Magnetism, the science which treats of the phenomena of t load-stone.

Mechanical Powers, instruments for adding to animal forc as the lever, pulley, wedge, screw, &c.

Menstruum, any liquid which dissolves and acts chemically any solids.

Meridian, a line passing from the north pole to the south pol through the zenith of any place.

Metals are distinguished by their weight, splendour, and du tility, and modern chemistry has detected nearly fort kinds, of which platina, the heaviest, is 23 times heavi than water.

Microscope, any instrument by means of which an object, c its true image, may be seen much nearer, and cons quently much larger.

Mirror, a reflecting surface, *plane*, *concave*, or *convex*, b means of which bodies may be seen of the natural, of a enlarged, or of a diminished size.

Mobility, the power of moving matter by a sufficient forc under certain laws of motion.

Momentum, the force acquired by different masses of matte moved with different velocities.

Nadir, the point under foot, opposite the zenith.

Node, the point of a planet's orbit at which it crosses th ecliptic, or earth's orbit.

Non-Conductors, surfaces of bodies which do not receive or transmit the electric power.

Obliquity, of the ecliptic, is the angle made by the plane the earth's orbit and the equator, in 1813, 23° 27 1-

Opacity, non-transparency.

Optics, the delightful science which treats of the laws of vi sion, light, and colours.

Parallax, horizontal, the angle which the earth's semi-diam ter subtends at a distant heavenly body.

Parallax, annual, the angle which the earth's orbit subtend to distant heavenly bodies.

rihelion, the place in a planet's orbit nearest to the sun, constantly in progression.

trifaction, the depositing of earthy matter, from water, on the surface of leaves, and other substances, forming an earthy or stony encrustation.

ndulums, heavy bodies suspended from a point, and performing vibrations backward and forward.

hysics, the science of matter and bodies, in the abstract.

lenum, space filled with matter, sensible or insensible to man.

neumatics, the science which treats of the properties of air.

owers opposing, elasticity producing expansion; and gravitation, producing compression.

rism, a glass wedge, used to refract light, and separate its different rays of colours.

rojectiles, bodies thrown into the air, having a parabolic motion.

ays, chemical, those of the violet end of the spectrum.

ainbow, an effect produced by the reflection and refraction of light on drops of rain.

arefaction, expansion, dilatation, increase of bulk.

ay of light, a single beam or impulse of light, sometimes called a pencil of light.

adius, the line which extends from the centre to the circumference of a circle.

adius-Vector, the line which extends from the solar centre of the ecliptical orbits of the planets, to the circumference of the orbit; and the areas described by the radius-vector are proportioned to the times, in which they are described.

epulsion, an opposite power to that of attraction, exerted at very short distances.

eflection of rays of Light, is their rebounding on striking a polished surface, which they always leave with the same inclination or angle as that with which they fell on it.

efraction of rays of Light, is the new direction which they receive on passing out of one medium into another.

etina, is the net of nerves which is spread at the back of the eye to receive the excitement of the rays of light.

aturation, when a fluid will hold no more of any substance in solution.

atellites, moons attached to planets.

ecular Motion, the motion in a century.

ine, the line drawn from the circumference of a circle, perpendicularly on its diameter, being half the chord of double the arch.

Synthesis, the composition, re-union, or re-generati
compound.

Syzygies, the moon's place, when the earth, sun, a
are in a straight line.

Tangent, a line touching a circle at one point.

Telescope, an arrangement of lenses or mirrors, by
observer is enabled to see an image of an obj
a larger angle, than he could with the naked e

Thermometer, an instrument to discover the heat
from many degrees below freezing to that
water or 212°.

Vacuum, a space unoccupied by sensible matter.

Vapours, the minute particles of fluids separated by
floating in the air.

Velocity, the space which any body moves through
time.

Vibration, the action of a musical string, or of t
surfaces of bodies when struck.

Volatile, the disposition of bodies to evaporate.

Zenith, the point over head.

Zodiac, a space in the heavens, extending eight d
each side of the ecliptic within which space
moon, and planets, move.

Zone, spaces on the earth's surface in which dista
mena appear, in regard to the seasons and leng

INDEX.

rest and fix their attention. The study of Geography no longer prove an irksome task, to perplex the mind and burden the memory, but will become a delightful exercise, a sort of mental recreation, which, like some juvenile amusement, will constantly cheer and enliven the pupil's exertions and prompt him forward, almost unconsciously, to the attainment, of one of the most difficult, useful, and ornamental branches of education. Thus to awaken the curiosity of the learner, and thus to allure him on the path of science, so as to convert what is usually regarded as *hard labour* into real pleasure, appears to be the grand secret of the teacher's art. This peculiar excellence distinguishes your system from all others, and gives a claim to general patronage which none can rival. Indeed, it combines so many excellencies and advantages, that a fair trial only is necessary to ensure it the approbation of every intelligent and judicious instructor of youth."

Rev. Chauncey A. Goodrich, Professor of Rhetoric in Yale College, observes—

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